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ON THE CLIFFS AND EXOTIC BLOCKS OF NORTH SWITZERLAND.

THE cliffs and exotic blocks that occur along the north border of the Alps and Carpathians have long remained as exceptional in occurrence and as difficult of explanation as were for years the so-called newer gneisses lying upon the early palæozoic sediments of northwest Scotland. The following paper is a brief summary of the work of two summers along the cliff-belt in Switzerland, chiefly in the region of the Lake of Lucerne where these phenomena are most typically developed. It will be my endeavor to present and discuss some of the problems which this work has suggested rather than to give a description of the region.

Introduction and definition of terms.—A glance at a good geological map of Switzerland[1] shows that the northernmost chains of the Alps, striking about E. N. E.–W. S. W. between Interlaken and the Upper Rhine valley (near the Sentis) are composed of Cretaceous strata with only rarely a patch of Jurassic rock exposed in the more deeply eroded anticlines and with Tertiary deposits filling in the synclines and in places reaching up over the backs of the more depressed Cretaceous folds.

These Tertiary beds require our first attention. They consist of a thick series of gray or bluish slaty clays, shales and marls with subordinately included banks of limestone, sandstone, brec-

[1] V. Geologische Uebersichts Karte der Alpen, by DR. FRANZ NÖE 1 : 1,000,000, Vienna, 1890, $2.50.

cias and conglomerates of early Tertiary (Eocene) and everywhere known under the name of *Flysch*. The thickness of the whole is, because of complicated movements which have taken place and the monotony of its petrographical characters, very difficult to determine. It has at some points been pinched out to a few feet; at others it is apparently several hundred feet in thickness.

This formation known as the Flysch is of especial interest to us because it is in it that the "cliffs" occur. The geological term "Klippe" or cliff, if we translate the term, was originally applied on account of the striking and abrupt manner in which these masses rise above their level or gently rolling Tertiary (Flysch) surroundings like cliffs above a beach. As geologists have learned more of the true nature of these masses, the term has come to take on a more definite geological significance, and is now somewhat loosely applied to island-like masses of rock which are stratigraphically, palæontologically, petrographically, and usually orographically foreign to the region in which they occur. Thus the Mythen overlooking the Lake Lucerne a short distance east of Brunnen and the Rigi are good types of the class —isolated masses, striking in appearance and composed of strata which have been found *in situ* nowhere else in all Switzerland.

To the rocks found in the cliffs the term "exotic" has been applied to express their foreign nature and to distinguish them from the "erratic" material brought down by the glaciers.

The exotic material of the cliffs consists of masses of dolomites, marls, shales and sandstones in certain of which characteristic Triassic and Jurassic fossils have been found. It lies upon or more or less imbedded in the soft Tertiary Flysch shales and the masses of it range in size from the smallest angular fragment up to cliffs a half mile and more in length and several hundred feet in height.[1] Of these the smaller blocks which were obviously loose, disconnected masses have been long known as "the exotic blocks" of the Flysch, while the more pretentious masses which on account of their size were *apparently in situ*, were termed

[1] For comparison v. Neumayr's description of the Carpathian cliffs which are often much larger than this. Erdgeschichte, Leipzic, 1887, Vol. II., p. 672.

"cliffs." A careful comparison of the cliff masses however with the exotic blocks showed that the two are the same. In point of size as well as facial development no distinction could be established between them, for the same strata containing the same fauna occur in both and in point of bulk the exotic block masses were found to occur in all sizes up to those of the smaller cliff masses. In the accompanying map the distinction between the two is a purely arbitrary one, the attempt being made simply to indicate the masses previously recognized as "cliffs" in the literature of the subject for convenience in discussion.

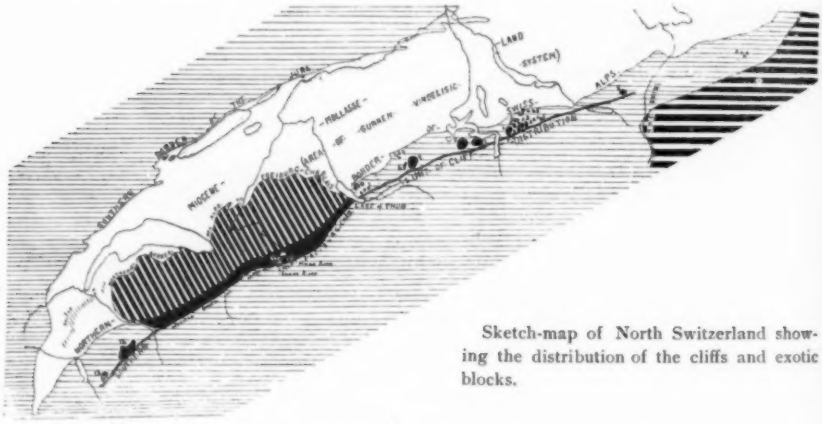
Historical.—Before proceeding to the results of my own studies I may introduce a brief sketch of previous work. On account of the scarcity of fossil remains in them the Swiss cliffs were long thought to be in some unexplained way mere abnormal developments of the strata of the adjacent chains and to be therefore of Cretaceous age. The petrographic similarity of one of the cliff strata now known to be Jurassic, to the Swiss Cretaceous Seewenkalk gave color to this idea. In 1875 Professor F. J. Kaufmann succeeded after long and patient search in discovering a set of fossils which proved beyond all doubt that the cliff masses on the Lake of Lucerne (Mythen, Buochserhorn, Stanzerhorn, and also the group to the southwest by Giswyl) contained a strata of Jurassic age.[1] Subsequent studies especially those of Stutz[2] have confirmed this and added to our knowledge of the fauna. The group of cliff-like masses to the east of the Mythen Iberg (see map) were at this time not recognized as belonging to the cliffs, as Kaufmann had in 1871 after a brief reconnoissance declared them on stratigraphical grounds to be a transition deposit between the uppermost Cretaceous and the base of the Jurassic. In 1889 Professor Steinmann upon further examination compared the strata here found in part with the Trias and Jura of Algau in the East Alps and held them to be of corresponding age. My own studies in 1891 and 1892 con-

[1] F. J. KAUFMANN, Fünf neue Jurassier, Jahrbuch des Schweits. Alpen Clubs, XI. Jahrgang, separate.

[2] STUTZ: Das Keuperbecken am Vierwaldstättersee, Neues Jahrbuch, 1890, II., p. 99.

firmed this view, as I succeeded in finding fossils which showed that these masses possessed in the main the same faunal peculiarities as the cliffs which Kaufmann had described farther west.

Exotic and Helvetian series compared.—The finding of fossils added rather than otherwise to the difficulty of understanding the cliffs because it marked more sharply than before the contrast between the exotic or cliff series on the one hand, and the normal or Helvetian series on the other. A brief tabular summary



Sketch-map of North Switzerland showing the distribution of the cliffs and exotic blocks.

of the cliff strata (including those in the exotic blocks and the Freiburg-Chablais Alps) will bring out more clearly this distinction:

SUMMARY OF THE CLIFF STRATA.

Trias.

1. *Lower Muschelkalk*, black limestone w. *Spirigera trigonella*, Schl.; *Aulacothyris angusta*, Schl.; *Coenothyris vulgaris*, etc. Not known in Switzerland outside of exotic series.

2. *Diplopora limestone*, gray to yellow, streaked with yellow dolomitic portions w. *Diplopora annulata*, Schfl; D. *macrostoma Gümb*, etc. Not known in Switzerland outside of exotic series.

3. *Rauhwacke and Gypsum.*—Found in Helvetian series also.

4. *Raible Marls*, dark gray to black, sometimes sandy, with *Equisetum columnare*. Unknown in Switzerland outside of exotic series.

5. *Rötidolomite*, yellow to rust colored, compact, crystalline. Found in Helvetian series.

6. *Haupt Dolomite*, hard, gray, sugar-grained dolomite, with angular fracture, very characteristic in the landscape. Found in Switzerland only in the exotic series.

7. *Rhätic*, gray to black crystalline limestone with *Avicula contorta*, very characteristic. Not found in Switzerland outside of the exotic series.

Jurassic.

1. *Liasic Fleckenkalk*, gray, brittle limestone w. black spots as if colored by bitumen. In Switzerland restricted to exotic series.

2. *Crinoidal Limestone of Lias*, brown to red, colored by iron; *Terebratula erbaensis*, Suess; *Rynchonella mutans*, Rothpl. In Switzerland only in exotic series.

3. *Crinoidal Limestone of Dogger*, like last, with *Pecten verticillatus* Stol., *Ammonites Sowerbyi*, etc. In Switzerland known only in exotic series.

4. *Birmensdorf beds.*—"Calcaire concrétionné" (?), hard, gray limestone in small rounded or lens-shaped masses imbedded in gray clay shale with (?) *Phylloceras*. Found only in exotic series in Switzerland.

5. *Malm.*—"Châtel limestone" of Studor with *Aspidoceras acanthicum* Opp., *Aptychus punctatus* Park, etc. Found only in exotic series.

6. *Radiolarian Chert.*—Red with iron, filled Radiolaria and associated with red clay. In Switzerland only in exotic series.

7. *Aptychus Limestone*, red and white fibrous limestone poor in macro-fossils (*Aptychus and Inoceramus*) but rich in *Foraminifera*. In Switzerland found only in exotic series.

Cretaceous.

Berrias beds, gray shales with *Aptychus angulicostatus*. Found also in northern chains of Swiss strata.

It will be seen that of the fifteen formations found in the exotic

series three only—the Rauhwacke with the associated gypsum; the Rötidolomite and the Berrias beds, *i. e.*, two near the bottom and one at the top of the strata—are also found in the normal Helvetian series. In the strata between these we find in Switzerland in the Trias, which is in general but weakly developed, nothing at all to correspond to the characteristic Muschelkalk, Haupt dolomite, Contorta beds (Rhätic) etc. In the Jurassic of Switzerland we find a series of clay shales, sandstones, iron oolites and gray crinoidal limestones with fossils of middle European type and differing throughout from those found in the cliffs. These are followed by thick series of dark colored limestone with Jura facies in general.

Geologic relations of cliffs to their surroundings.—The differences which we thus see in the facial development of the Swiss strata and of the cliff or "exotic" strata of *the same age* lying side by side with them in north Switzerland, and beside which the correspondences seem quite insignificant, are so striking as to stimulate inquiry as to their cause and possible explanation.

The attempt was therefore first made to determine the relations which the cliff masses sustained to the surrounding Helvetian chains, to determine if possible whether these masses extended *down through* the Flysch above which they rose or simply lay as rootless block masses *upon* the Helvetian chains. It will naturally be impossible for us to enter here with any detail into a line of evidence based to a great extent upon local structural relations of the region studied and involving a considerable mass of local description and local facts.[1] There are, however, certain general features common to and characteristic of the cliffs to which I may refer. One line of such evidence is furnished by the conditions of the strata in the cliffs as contrasted with those near them. A second by the more general relations of the cliffs to the surrounding chains.

If the cliff masses be superficial in their nature, they must have been thrust from the side, and we should in that case find evidence of such overthrust in the cliff masses them-

[1] For these details cf. Beiträge z. geol. Karte d. Schweiz, Vol. XXXIII, Bern, 1893.

selves. Such we do find. All of the cliff strata show evidence of great pressure; they are fractured and often traversed thickly with calcite veins (especially the harder Haupt-Dolomite and the Tithon); the less brittle rocks are strongly contorted and full of cleavage structure and of slickensides (especially the softer Tithon beds of the cliffs); certain of the less resistant beds (as the Aptychus limestone and Raible marls on the Roggenstock and Laucheren) are greatly thinned by pressure or in places entirely pinched out. All these features are evidence of strong pressure, but more striking is the further fact in this connection, viz., that all evidence of disturbance, such as is found in the cliff masses and I may also add in the larger exotic block masses near the cliffs, is entirely wanting in the Helvetian strata all about. It might of course be said that the evidences of pressure mentioned would be as well accounted for if the cliffs were thrust powerfully upward from below through the younger Swiss strata upon which they lie, as has been thought by Professor Neumayr to be the case with the Carpathian cliffs. But at Iberg and in the other larger cliffs in the region of the Lake of Lucerne it is hard to see how such an upward thrust could have taken place powerful enough to force masses half a mile long through beds of limestone (Urgonkalk, Gault and Cenoman) several hundred feet thick without showing some evidence of the disturbance in the rock thus thrust through at least in the immediate vicinity of the cliffs. Such evidence, however, we fail to find either in the alteration of the general strike or dip of the Swiss beds or in indications of pressure in the minute structure of the rock itself. This contrast indicates that the one set of rocks has undergone disturbance which the other has not, and that the two have been affected by a different set of dislocations. In the Roggenstock near Iberg the cliff strata lie nearly horizontal. The Swiss strata below them are also nearly horizontal at this place. This position is what we would expect were the cliff thrust from the side, but very difficult to understand if they were thrust from below. The long, low mass of the Laucheren-Mördergrube cliff presents also the same difficulty on the latter hypothesis. Again the strata

on the Roggenstock and the Kleine Mythe are not only nearly horizontal but actually in *inverted order* with younger strata below and older above. This complete inversion seems impossible to explain on the theory of an upthrust yet it is a common phenomenon accompanying powerful lateral thrust.

Without entering here into further details I may mention one or two facts of more general significance bearing on the relations of the cliffs to the surrounding strata. One very singular feature is the fact that the Swiss cliffs and the exotic blocks as far as I know them, invariably occur in the Tertiary Flysch shales. In spite of the extensive erosion which has attacked the whole region in which the cliff phenomena occur *the cliffs are found nowhere where the Flysch has disappeared.* If they came up from beneath, through the Cretaceous and Tertiary, we should surely expect to find hard and resistant limestones and dolomites of the cliffs at some points remaining after the softer Flysch shales had been eroded away, or at least some point where the cliff had not been thrust entirely through the Flysch and exposed between the jaws of a Cretaceous anticline on its way through. We find it difficult to see on the upward thrust hypothesis why the whole exotic phenomena should be dependent upon the presence of the Flysch. At Iberg we have a striking example of this dependence. It will be seen on a good general map that owing to a local sinking of the Swiss chains at this place, Flysch shales extend farther southward than they do to the east or west of here, continuing up over the top of the Roggenstock-Fallenfluh anticline, though usually confined to the troughs, and here also peculiarly enough the cliffs occur, *i. e.*, on the top of this anticline though more commonly the exotic phenomena appear in the Flysch-filled synclines only. If the Iberg cliffs could have come from beneath and be therefore associated in origin with the Swiss chains, it is difficult to understand why in the the strike of the anticline to the east and west of their present position they should disappear as soon as the Flysch disappears. This relationship between the cliffs and the Flysch becomes intelligible, however, as soon as we conceive of the exotic masses as thrust from the side and *thrust over Flysch* upon which and in

which they lie, so that the erosion of the latter would necessarily bring about the erosion and disappearance of the former. Another striking feature of the cliff masses is to be found in the fact that in spite of the confusion into which they have been thrust they give evidence of a generic if not of an earlier actual physical connection with one another from the fact that they show in certain cases a notable *correspondence of irregularities* in two adjacent cliffs. Thus the Roggenstock and the adjacent Laucheren cliffs both present to us Triassic "Haupt Dolomite" lying upon Jurassic Aptychus limestone, and the striking correspondence of strata in the two neighboring masses of the Stanzerhorn and the Buochserhorn has been already remarked by Stutz in his description of them. This would be what we should expect were the cliff masses part of a general overthrust, much confused as a whole, but still showing in places evidence of the original unity of the entire mass.

The last two points suggest a third. If the cliffs are part of a general overthrust, as the whole region has been strongly eroded we might expect to find traces of the original overthrust in the material brought down by the agencies of erosion and deposited along the foot of the Alps. Singularly enough we do find in the Miocene lowlands stretching along the north border of the Alps a vast amount of material in fragments from a fraction of an inch to five or six feet in diameter and much waterworn as a rule, but often fossiliferous, and showing in striking degree the same facial development as the cliff series. This material occurs in thick banks of a more or less consolidated conglomerate known under the name of *Nagelfluh*. Dr. Früh, of the University in Zurich, who has given us the most complete account of this conglomerate, described from it "Muschelkalk," Diplopora Limestone, Rauhwacke, Haupt Dolomite, Rhaetic, "Fleckenkalk," Hierletz beds, Aspidoceras beds, Radiolarian chert and Aptychus limetone. A comparison with the table of cliff strata given above will show the striking similarity between the two. The evidence of very extensive erosion of cliff material thus afforded by the study of the Nagelfluh furnishes additional proof that the cliffs are but the last remnants of a once

much more extensive cap covering the outer Alpine chains. Were the cliff masses thrust upward from below through the Helvetian Cretaceous and Tertiary anticlines we could hardly expect to find so much eroded material derived from them as we do indeed find in the Nagelfluh. For in that case we should expect the cliff masses to be in some places less completely thrust through the encasing younger strata, and therefore more or less completely hidden by them, so that the cliffs would become exposed to its action only after erosion had removed the younger covering. We should therefore expect to find the cliff masses increasing in number and extent as deepening erosion exposed them more and more to view. We find, however, abundant evidence that the cliffs cover a much less extensive area today than formerly. Again in case of an upthrust from below we should further expect that the percentage of cliff strata in the material carried from the surface by erosion would have been less in former times than it is today—it could surely not have been greater. An examination of the stream beds coming from the cliff belt shows today a decided preponderance of Helvetian over cliff strata in general. Instead now of finding in the Nagelfluh, as we would expect an even greater preponderance of Helvetian over cliff strata we find the amount of Helvetian rocks insignificantly small. This striking fact can, as it seems to me, only be explained on the ground that the Helvetian strata were at the time of the deposit of the Nagelfluh to a considerable degree protected from the erosion which attacked and carried down to the Miocene seashore vast quantities of cliff material. To assume that the protection consisted in a cap of cliff strata which covered large portions of the outer chains would be in harmony with the theory of overthrust but seems to be quite inexplicable on the hypothesis that the cliff masses were pushed up through the strata where they occur.

With this imperfect summary we have endeavored to give some of the more important reasons for believing that the Swiss cliffs are superficial phenomena lying upon the surface of the normal Swiss series and immediately upon the Flysch and have been therefore thrust from the side into their present position.

Origin of the cliffs.—We now approach another, perhaps the most difficult question relating to the cliffs—the question of their origin. As the cliff masses themselves do not furnish us direct evidence of the direction from which they may have been thrust, we are led to look for other and indirect evidence. The solution of this problem must depend therefore in great part upon the study of the faunal characters and relationships of the exotic strata, in connection with the stratigraphy, their petrographic characters and their distribution. An important circumstance and one which has probably retarded more than anything else the acceptance of the idea of overthrust, is the fact that, in distinction from the analogous phenomena in France, Scotland and America, in Switzerland no rock masses are known which contain *in situ* the strata and fossils found in the cliffs and whence therefore the cliff masses could be supposed to have proceeded. It has seemed therefore quite impossible to trace them to their original home or basin of deposit. In looking for the basin of deposit of the cliff series the region to the south of the cliff zone is soon seen to be excluded for reasons already indicated, viz., that the faunal and other characters of the exotic series are so entirely distinct from those of the Helvetian series which occupy all the district of the Glarnese Alps to the south, and although to the south still further strata bearing the same facial characters are known in the vicinity of the Italian Lakes the extreme distance of these outcrops, sixty-five miles or more, as well as the physical character of the intervening Alps, effectually precludes the possibility of deriving the cliffs from that quarter. As the cliff masses were evidently not introduced from the east or west we are led to look to the plains to the north (schweizer'sche Hochebene). Many years ago the famous Swiss geologist Studer for reasons quite different from those here considered was led to believe in the existence of a sunken mountain system[1] buried beneath the young (Miocene) strata of the Swiss plains which has since been assumed to exist by numerous other geologists and has received the name of "das Vindelisische Gebirge" from Professor Gümbel.

[1] Cf. Profiles in STUDER's Geologie der Alpen, Vol. II., p. 434–436.

The study of the cliffs has brought us back to this old hypothesis with renewed assurance of its innate probability.

In considering this question it is important to have clearly in mind the relations sustained by the "East Alps" (that portion of the Alps lying to the east of the Rhine) on the one hand, and by the Freiburg Alps to the west of Lake Thun on the other to our cliff masses. (Compare accompanying map.) The East Alps bound the cliff zone on the east as do the Alps of Freiburg on the west. Both the East Alps and the Alps of Freiburg have long been known to contain a Mesozoic rock series facially quite distinct from those of the normal Swiss mesozoic, so that the term "Helvetian (Swiss) series," "East Alpine series" and "Freiburg series" have been used to distinguish the three. Since the time of Brunner's discovery of *Avicula contorta*, a characteristic East Alpine upper Trias form, in the Alps of Freiburg (Stockholm) it has been repeatedly pointed out that there are numerous features of resemblance between the strata of these two territories lying at either extremity of our cliff zone. Realizing the importance of establishing this point and the relations of the cliffs to the whole, I undertook to make a tabulation of the strata and fossils of the Trias, Jura and lower Cretaceous (all occurring in the cliffs and exotic blocks) of (1) the "East Alps," (2) the cliffs and exotic blocks, and (3) the Alps of Freiburg. The result of this comparison has shown that the strata of all three have essentially the same facial development, and might belong therefore to the same basin of deposit. (For the geographic relations of these regions see map.) The importance of this point for the understanding of the cliffs can hardly be overestimated. It shows us that the basin of deposit of the East Alpine series was not confined to the east of the Rhine, but extended, or at least repeated itself, far to the west of it along the north border of the Alps; it shows us further that the cliff zone stretches between the East Alps and Freiburg Alps as the remnant of a once more or less continuous deposit connecting the two; and it leads us to suspect that on the same basis of unity whatever greater movements have taken place in the cliff

masses would be very likely to have similarly affected the strata of the Alps of Freiburg. In order to test this point I visited the Alps of Freiburg in the summer of 1893. We ought here to be able it was thought (1) to distinguish clearly between the "Freiburg" (exotic) and the normal "Helvetian" series and therefore determine by direct examination at the place of contact between the two kinds of rocks whether the Freiburg strata show evidence of an overthrust southward upon the Swiss chains as we had been led to assume was the case with the cliffs. The results of these investigations, published elsewhere,[1] showed evidence of an overlapping of Freiburg strata southward 4.5 kilometers upon normal and characteristic Helvetian beds, which were disclosed in the deeply cut valleys of the upper Simme and Saane rivers. Here, too, we find the same sharp contrast between the excessively disturbed and often inverted Freiburg strata and the horizontal Helvetian series that we noted in the cliff zone to the east; also similar breccias occur on the plane of overthrust. Here, too, as in the vicinity of Iberg, the overthrust is everywhere over the Flysch, so that the time of the movement corresponds to the time of movement farther east.

Another feature which favors the view of overthrust from the north is to be found in the peculiar distribution of the exotic material over the belt occupied by the cliffs. Here I cannot perhaps do better than to refer to the accompanying sketch map where this feature is indicated, and point out what the map is intended to show.

EXPLANATION OF THE SKETCH MAP.

The map of North Switzerland shows the distribution of the cliff masses and "exotic blocks" of North Switzerland in the cliff zone extending from Lake Thun to the Rhine and the relation of this cliff zone to the surrounding country. All portions colored black, either solid or diagonally striped, represent exotic material. The size of these masses has been necessarily exaggerated in the map, though the relative size of the different

[1] Berichte der naturforschenden Gesellschaft zu Freiburg in Baden, Vol. IV., No. 2.

exotic masses among themselves and their relative abundance has been expressed as well as possible.

In this cliff zone the rounded black patches represent the larger cliff masses as follows:

No. 1 (eastermost cliff known) = Berglittenstein cliff, in the Toggenberg syncline near Grabs.
No. 2 = Roggenstock cliff, near Iberg in Upper Sihl valley.
No. 3 = Laucheren-Mördergrube cliff, near Iberg.
No. 4 = Schien-Gründelhüttle cliff, two masses near Iberg.
No. 5 = Zweckenalp cliff, near Schwyz, Lake of Lucerne.
No. 6 = Die Mythen cliffs—three masses near Schwyz.
No. 7 = Buochserhorn cliffs—three distinct masses according to Heim[1]; five according to Stutz[2]; on Lake of Lucerne.
No. 8 = Stanzerhorn cliff—near Lake of Lucerne.
No. 9 = Giswyl cliffs—several more or less disconnected masses.
No. 10 = Niederhorn cliffs—three small exotic masses described by Kaufmann,[3] near the northwest foot of the Niederhorn.
(I may also mention here for completeness, farther to the west.)
No. 11 = Lenk-Lauenen cliffs[4]—exotic masses in the Upper Saane valley between Lenk and Lauenen.
Nos. 12 and 13—Westernmost cliff-like masses = Thônes masses—thought to be "cliffs," to the southwest of the Chablais region.[5]

In this same Thun-Rhine cliff zone are also represented, as well as could be in a map of this size, the distribution of the smaller exotic masses or "exotic blocks" (in general those masses that are less than 25 meters in diameter) as far as I have been able to determine their presence either by personal visit or, as in one instance (H), from the literature alone. There is undoubtedly much more such material in the Flysch which further search will reveal. The principal groups of exotic blocks are indicated on the map by the following letters:

[1] HEIM: Unser Wissen von der Erde, Geogr. Anstalt. Leipsic, 1889—see map of Lake Lucerne.

[2] Das Keupenbecken am. 4- Waldstätter See, Neues Jahrbuch, etc., 1890, II. p. 99 ff.

[3] Beiträge z. geol. Karte der Schweiz, Vol. XXIV., pp. 282–285, 524.

[4] See Berichte der Naturforsch. Geo. zur Freiburg i B., Vol. IX., No. 2, p. 122 ff.

[5] See FAVRE: Carte geol. d. voisines du Mont Blanc, Winterthur, 1862.

A Easternmost group = Bolgen group — west of the Iller valley.
B = Barlaui Alp group — northeast of Iberg.
C = Tannstaffelalp group — in Wäggi valley east of Iberg.
D = Steinibach group, four to six kilometers north of Iberg.
E = Geschwend-Surbrunnen group — one to two kilometers north of Iberg.
F = Gründelhüttli group, west of Iberg.
G = Giswyl group, near Giswyl.
H = Flühli group, northwest of Giswyl.
I = Habkern group, in Habkern valley.

At the south edge of Freiburg Alps southwest of Lake Thun may be mentioned:

J = Lenk-Lauenen group, between Bad Lenk and Lauenen.

At the west end of the Rhine-Thun cliff zone are seen the Alps of Freiburg and Chablais. It should be noted that the southern edge of these Alps are in line with the southern limit of cliff distribution; the northern border, on the other hand, is not in line with the northern border of the Swiss Alps, but extends in the form of a bow far out into the Miocene plains (Molasse land). In the upper valleys of the Saane and Simmen rivers (see map) where these valleys are cut deeply into the Freiburg strata typical Helvetian strata, Flysch and Nummulitic limestone have been found lying below Triassic and Jurassic strata in Freiburg facies,[1] indicating that the Freiburg Alps at this point were thrust southward two and one-half to four and one-half kilometers over the Helvetian strata. We have, therefore, drawn a dotted line across the southern portion of the Freiburg-Chablais zone to indicate the probable zone of overthrust and colored all south of this zone black. It may, however, be that this overthrust is of a more local nature. The remainder of the region is striped diagonally black and white.

To the east of the Rhine-Thun cliff zone the area of the strata in East Alpine facies is roughly indicated by alternating

[1] Cf. Berichte d. Naturforschende Gesell. v. Freiburg i. B. Vol. IX., Part 2, p. 122, 1894.

bands of black and white running horizontally. It will be seen that the East Alps do not begin at once at the Rhine, but there is a promontory-like wedge of Helvetian strata (fine black horizontal lines) projecting along in front of their north border a considerable distance. In this wedge occur the enigmatical exotic bowlders by Bolgen (A of the map).

It will be noticed that the cliffs and exotic blocks are scattered with considerable irregularity along the north border of the Alps over a belt of Helvetian strata (indicated by the light horizontal lines) from about two to nearly nine kilometers broad. The exotic masses do not extend anywhere south of this strip. In the vicinity of Iberg, which has been studied with especial thoroughness, may be seen how the whole region between the southern border of the cliff belt and the northern border of the Helvetian chains is covered with exotic material. Abundant as is this exotic material here, every trace of it disappears a short distance south of the cliffs. This most striking limitation of the distribution of the exotic strata southward all along the Thun-Rhine cliff belt is precisely what we would expect if there had been an overthrust like that hypothecated.

Summary and conclusion.—To recapitulate, we have found Alpine facies in the Freiburg Alps at the west end of the cliff zone, Alpine facies again at the east end in the "East Alps," Alpine facies also in the superficial cliffs and exotic blocks between these two points. In the Nagelfluh we have evidence of a former much greater extent of the cliff masses. In the cliffs themselves and in the fact that cliffs and exotic blocks lie invariably in Flysch we find evidence that they were thrust over Flysch; lastly, in the supposed Vindelicic system beneath the Miocene plains north of the cliffs we have a place—and apparently the only place—from which it seems possible that the cliffs could have been derived. These conclusions afford us the most satisfactory explanation of the cliff belt and the Freiburg-Chablais region as a whole and their relations to the East Alps, and render intelligible the presence of the Swiss plains—sunken between the "horsts" of the Alps and the Jura—and the isolated position of the Jural mountains on the far side of them.

Bearing in mind the geographic relations of Cliff-Freiburg-Chablais exotic belt we can, in accordance with the above view, reconstruct in some measure the geographic conditions of this part of the world in early and middle Mesozoic times. According to this view there extended in Jura-Trias times between the present site of the Alps and the Jural mountains opposite a Vindelicic sea in which East Alpine life and conditions prevailed. A comparison of the exotic (Vindelicic) series with the Helvetian and Jurassic faunas shows beyond doubt that the cliff series represent deposits in comparatively deep water.[1] We may, therefore, assume that the sea of this region was at that time characterized along the Vindelicic area by a deeper sea. If the passage from the more shallow Helvetian to the deeper Vindelicic sea was not too abrupt we might therefore expect to find indications of transition in the outermost (northernmost) chains of the Alps. Hence the fact pointed out by Stutz that along the Axenstrasse on the Lake of Lucerne the outer chains contain certain subordinate beds of more Alpine facies (Diphya-beds, "Stramberg beds"—strata with Terebratula janitor) has a peculiar interest. And the fact that certain of the cliff strata have been shown to present facial similarity to others occurring on the north side of the Vindelicic region would further bear out this conception by showing a relationship between the cliff series and strata to the north.

E. C. QUEREAU.

[1] As evidenced, for example, by the presence of Aptychus limestone, Globigerina shales, Radiolarian chert and associated red clay in the cliffs.

THE PREGLACIAL VALLEYS OF THE MISSISSIPPI AND ITS TRIBUTARIES.

It is the purpose of this paper to bring together such data as are available on the subject of preglacial drainage lines, in the northern part of the Mississippi basin. It is thought that such a presentation will aid in drawing inferences concerning several important questions connected with glaciation; among which are the preglacial altitude of the region, the differential crust movements, and the effect of glaciation in enlarging and deepening valleys. It will be mainly a contribution of facts. The questions upon which these facts have a bearing need the full light of these and other data before inferences of much value can be drawn.

This district has, in some respects, advantages not possessed by other districts. (1) It has a driftless area in which the breadth and depth of large preglacial valleys can be accurately determined. The location of this driftless area is particularly fortunate, being over the line of so prominent a valley as the Mississippi, a valley which crosses drift-covered areas both above and below the driftless area. (2) In some parts of the glaciated region the oldest drift sheets are not well represented, and it often becomes difficult to decide whether a given valley was cut to its present depth in preglacial time or has been deepened in inter-glacial or post-glacial times. In the region here discussed some of the valleys are filled with the oldest drift sheet of which we have knowledge, and their floors have not since been subject to the scour of streams. We can, therefore, confidently place their excavation before the first ice invasion. (3) In this region the valleys of some of the main arteries of preglacial drainage are found running parallel with the longer axis of one of the deepest lake basins, the basin of Lake Michigan. A study of the contours of these valleys, combined with a study of the lake basin should help to an understanding of the influence of the ice-

sheet in giving this basin its low altitude. The slope of preglacial valley floors will throw light upon differential crust movements which have affected the basin. Unfortunately we have as yet very few data from Wisconsin, a district which should furnish many important data when the reports of its borings are collected and its preglacial drainage lines worked out.

COURSES OF THE MAIN PREGLACIAL DRAINAGE LINES.

Concerning the course of the Mississippi above the mouth of the Minnesota River very little is known. It is probable, however, that its drainage area was about as great as that of the present stream. From the mouth of the Minnesota southward to the mouth of the Wapsipinnicon River below Clinton, Iowa, a distance of about 300 miles, the present stream follows the line of the preglacial, the only deviations from that line being slight encroachments on the bluffs of the old valley, as at Fulton, Illinois, where a rocky point belonging to the old west bluff has been cut off by the present stream. Below the mouth of the Wapsipinnicon, the present stream for a distance of forty miles (to Muscatine, Iowa) is in a new course. The bordering districts are heavily covered with drift and it is not an easy matter to determine the course of the old valley. I expressed the opinion, some three years ago, that the course was southeastward through the Green River basin to a bend of the Illinois River near Hennepin.[1] This opinion was based upon the existence of a low tract of country connecting the Mississippi with the Illinois along the north border of the Coal Measure formations. It has since been discovered by Professor J. A. Udden that a similar tract of country more completely concealed by the drift follows the northern border of the Coal Measure area westward and southwestward from the mouth of the Wapsipinnicon through Scott and Muscatine counties, Iowa, to the old valley below Muscatine. Which of these courses was taken by the preglacial upper Mississippi is being made a matter of special investigation by Professor Udden, and we look for an early publication of the results of his investigations. He informs me that the lowest

[1] Proc. A. A. A. S., Rochester Meeting, Vol. XLI., 1892, p. 176.

altitudes yet brought to light by borings are along the line leading through eastern Iowa, but that the line leading southeastward to the Illinois has been less perfectly tested by borings and hence may contain a channel equally deep.

From Muscatine to the Mississippi embayment of the Gulf above Cairo, Illinois, the present line of the Mississippi is nearly coincident with that of the preglacial line. The most important diversion is at the lower rapids just above Keokuk, where for a distance of twelve miles the present stream is cutting a new valley parallel to and slightly east of the preglacial course. There are slight diversions of the present stream into the edge of the bordering bluffs at two points below St. Louis, similar to the one noted above, at Fulton. One of these is at Fountain Bluff and the other at Thebes, Illinois. The preglacial course is plainly traceable around the rocky points which the present stream cuts off, and is utilized at flood seasons in both cases.

In the district between St. Paul, Minnesota, and the mouth of the Illinois the eastern tributaries of the Mississippi, with the exception of the Wisconsin River, were very small, owing to the existence of a large parallel valley traversing southern Wisconsin and western Illinois, as shown below. Western tributaries of the Mississippi appear to have drained a wide area but their courses have not as yet been worked out, for the region is very heavily covered with drift, and a large number of borings will be necessary to establish, even approximately, the course of preglacial drainage. It is certain that the present and preglacial systems of drainage are coincident in but a few places.

The preglacial Rock River drainage basin apparently extended to the Mineral Ridge axis on the northwest and to the Niagara escarpment on the east. The course of the main line of drainage was probably along the axis of the trough west of the Niagara escarpment. Whether the drainage of this trough was then divided, as at present, between Green Bay and Rock River, the writer is not prepared to judge, for this is a district which has not been personally examined and the published data are scarcely adequate to warrant a decision.

Rock River follows nearly its preglacial course from the Kettle

moraine in southern Wisconsin, southward to the mouth of the Kishwaukee, a few miles below Rockford, Illinois, where it turns to the southwest and follows a new valley to the Mississippi.[1] The preglacial course of the river is plainly traceable southward from the mouth of the Kishwaukee across eastern Ogle county to the vicinity of Rochelle, the drift being insufficient to fill the old valley to the level of the bluffs. From Ogle county southward across Lee and Bureau counties to the bend of the Illinois River at Hennepin, borings have shown the presence of a deep channel. Several have gone to depths below that of the rock surface a few miles to the west. Only one of these borings, the artesian well at Princeton, Illinois, has reached the rock floor. This shows a drift filling of 440 feet, and probably strikes the deepest part of the old valley, the rock floor being as low as at any point yet found in the course of the whole channel. There can scarcely be a doubt that the preglacial course of Rock River was southward along this line to the Illinois, and thence to the Mississippi, though we have as yet no borings, except the one at Princeton, which test its deepest portion at any point between the Wisconsin line and bend of the Illinois.

The courses of the preglacial tributaries of the Rock-Illinois are known only in a few instances, owing to the great amount of drift which conceals them. The Pecatonica Valley which enters from the west, just below the Wisconsin line, is mainly in a preglacial course and so are its main tributaries, Yellow Creek and Sugar River. The Kishwaukee is largely in a new valley and enters the Rock River Valley through a gorge at its mouth. The upper portion of the Illinois, including its headwater streams —the Fox, the Des Plaines and the Kankakee—are all in postglacial valleys. They cross a somewhat elevated limestone district which, like the Niagara escarpment to the north, seems to have formed the preglacial watershed between the Rock-Illinois drainage basin and the basin now occupied by Lake Michigan. They thus bring to the present Illinois the drainage of a large district which formerly discharged into the Lake Michigan basin.

[1] Changes of drainage in the Rock River basin in Illinois, by FRANK LEVERETT, Proc. A. A. A. S., Madison Meeting, Vol. XLII., 1893, p. 179.

Southward from Hennepin the drift deposits are so heavy that it has been found impossible to map out the courses of preglacial drainage. A basin or expansion of the valley just north of the mouth of the Sangamon River, and a very low altitude of rock surface for some distance to the east of this basin is thought to indicate the point where a large preglacial tributary enters from the east. The Sangamon drains a region which probably then, as now, discharged to the north, perhaps joining this large eastern tributary. South from the Sangamon River the preglacial tributaries were about the same size as the present, there being a well-defined rock divide between the headwaters of the south fork of the Sangamon and the lower portion of the Illinois. The western tributaries of the Illinois were probably small as were the present ones, owing to its nearness to the Mississippi.

The present Wabash River follows a preglacial drainage line from its bend near Covington, in western Indiana, southward to the Ohio River. The stream is in a new valley for a few miles above Covington but is again in a preglacial valley in the vicinity of La Fayette. It is probable that this preglacial valley leads westward past Oxford, Indiana, and thence south to the preglacial Wabash near Covington. From near Delphi, Indiana, to its source the Wabash is mainly in a new course. The headwater portion of the streams forming the preglacial Wabash may prove to have been in the Lake Michigan basin. But if so the connection with the Wabash is through a very much narrower trough than that occupied by Lake Michigan. Borings at North Judson, Winamac and Monticello, Indiana, situated near the line connecting the head of Lake Michigan with the preglacial valley at La Fayette, go to a level about 100 feet below the surface of Lake Michigan before entering rock. But within a few miles east of this line, rock ledges have an altitude as great as the surface of Lake Michigan, while immediately west of this line they rise 90–125 feet above that level. This trough cannot have, in the vicinity of Monticello, a breadth of more than ten miles. Monticello is situated near the middle of the trough. The probabilities are, therefore, against the existence of a much deeper channel in it.

Borings have been made at frequent intervals westward and northwestward from this trough across northwestern Indiana and northeastern Illinois and none of them show so low a rock surface as this line presents. They usually enter rock above the level of Lake Michigan. There seems, therefore, no ground for suggesting a southward or southwestward outlet of the Lake Michigan basin further west than the line which leads from the head of the lake to La Fayette, Indiana. Furthermore this seems the most probable line for a channel, since it follows nearly the western edge of the soft Devonian shales, where degradation would naturally proceed more rapidly than in the firm and resistant limestone ledges to the west.

The tributaries of the Wabash in its lower portion follow, to a large extent, their preglacial courses. The eastern tributaries drain a driftless region in Indiana, while the western drain a region thinly clad with drift in southern Illinois. From the latitude of Terre Haute and St. Louis southward, the Mississippi and Wabash seem to have divided the drainage of southern Illinois in preglacial times, about as they do at present.

The Ohio River seems to have been greatly enlarged by the ice invasion. But little study has been given the lower course of this stream. It is probable, however, that from southern Ohio to its mouth it follows nearly the preglacial line, since that portion was encroached upon but little by the ice-sheet. The upper course from eastern Ohio northward seems to have discharged to the Lake Erie basin.[1] The Muskingum Valley of eastern Ohio is thought by Professor W. G. Tight, to have discharged northwestward in preglacial times, instead of southward into the Ohio.[2] The data collected by Professor Tight make it appear quite probable that this valley was a tributary to the Scioto basin. The view that it continued across that basin into the Wabash seems less fully sustained.

[1] For a presentation of the evidence see Amer. Jour. Sci., Vol. XLVII., 1894, pp. 247–283. The paper referred to contains references to the literature of the subject, which is already quite extensive.

[2] A contribution to the knowledge of the Preglacial Drainage of the Ohio, W. G. TIGHT, Bull. Sci. Lab., Denison University, Vol. VIII., pp. 35–61. With two plates. Granville, Ohio, 1894.

ELEVATION AND SLOPE OF PREGLACIAL VALLEY FLOORS COMPARED WITH PRESENT STREAMS.

The Mississippi Valley.—In this discussion we assume for convenience that the upper Mississippi found its continuation from the mouth of the Wapsipinnicon through Scott and Muscatine counties, Iowa, to the preglacial valley below Muscatine. On a subsequent page we discuss the comparative elevations and slopes of the valley floors of the upper Mississippi and the Illinois.

In preparing the table which follows some difficulty was found in deciding upon distances. In the portion above Cairo there are few oxbows or other deflections from a direct course, hence the distances at high and low water stages are not greatly different, and the high water distance is usually taken. In the portion below Cairo the oxbows and deflections of the stream are numerous. The low water stage involves, therefore, a much greater distance than the high water stage. The distances given are the low water route. They are taken from *Dana's Manual.* The distance from Cairo to Memphis at high water stage is about 150 miles, or only two-thirds that of the low water stage. Between Memphis and the Gulf the distance at high water is estimated to be but 500 miles, or 350 less than the low water stage. Taking the direct course, the rate of fall between Cairo and Memphis at high water stage is 8.24 inches per mile, while between Memphis and the Gulf it is 5.23 inches per mile. Some interesting differences in the rate of fall between certain points at high water and low water stages appear in the upper Mississippi. Thus for a few miles above each of the rapids there is a greater fall at flood stage than at low water. The low water stage is below the usual rate of fall, owing probably to the barrier presented by the rock floor at the head of the rapids. This barrier has little effect upon high water stages, and the descent of the stream is, therefore, nearer the normal.

It is probable that the borings at Fort Snelling, St. Paul, Dubuque, Sabula, Fort Madison, Bellefontaine and East St. Louis, enter the deep part of the preglacial channel, though they may not mark the very lowest limit of erosion. The other borings probably strike shelves bordering the channel when not on

RATE OF FALL OF THE PREGLACIAL ROCK FLOOR AND THE PRESENT MISSISSIPPI FROM FORT SNELLING, MINNESOTA, TO THE GULF OF MEXICO.

Location	Dist. Miles	Low Water A. T.	High Water A. T.	Fall per Mile L. W.	Fall per Mile H. W.	Rock Floor A. T.
		Ft.	Ft.	In.	In.	Ft.
Ft. Snelling, Minn.	0	686	.....	.....	.....	486[1]
St. Paul, Minn.	6	683	702	6.00	.....	483[1]
Lake City, Minn.	55	658	.....	5.45	.....	495[2]
La Crosse, Wis.	68	628	643	5.30	5.75	504[3]
Prairie du Chien, Wis.	60	604	623	4.80	4.00	492[3]
Dubuque, Iowa	55	585	607	4.14	3.49	453[3]
Sabula, Iowa	36	572	592	4.33	5.00	429[4]
Fulton, Ill.	16	566	587	4.50	3.75	465
Le Claire, Iowa (New Ch.).	20	562	576	2.40	6.60	550
Rock Island, Ill. (New Ch.).	16	542	560	15.00	12.00	530
Muscatine, Iowa (New Ch.).	24	531	547	5.50	6.50	506
Near Wilton, Iowa (Old Ch.)	.....	.....	.....	.....	.....	400–[5]
Mouth of Iowa River	18	523	539	5.33	5.33	445–
Burlington, Iowa	24	511	527	6.00	6.00	430–
Ft. Madison, Iowa	18	502	518	6.00	6.00	365[6]
Near Montrose (Old Ch.)	.....	.....	.....	.....	.....	374[7]
Montrose, Iowa (New Ch.).	9	500	514	2.66	5.35	490
Keokuk, Iowa	12	477	494	23.00	20.00	470
Quincy, Ill.	38	458	476	6.00	5.68	413[8]
Hannibal, Mo.	17	450	467	5.64	6.35	362[9]
Louisiana, Mo.	25	437	453	6.24	6.72	380–[10]
Mouth of Illinois River	68	403	422	6.00	5.47	?
Bellefontaine, Mo.	17	402	420±	0.70	1.40±	295[11]
East St. Louis, Ill.	24.3	380	414	10.86	2.96±	284[12]
E. Carondelet, Ill.	6	377	412	6.00	4.00	330
Fountain Bluff, Ill.	100	313	357	7.68	6.60	300[13]
Thebes, Ill.	40	291	339	6.60	5.40	280[13]
Cairo, Ill.[14]	35	270	321	7.20	6.16	?
Memphis, Tenn.[15]	233	183	218	4.48	8.24	.....
Mouth of river	855	0	.....	2.56	5.23	.....

[1] N. H. WINCHELL: Amer. Geol., Aug., 1892.

[2] Geol. of Minnesota, Vol. II., p. 17.

[3] CHAMBERLIN and SALISBURY: Sixth An. Rept. U. S. G. S., p. 223.

[4] Data given by W. R. Oake, Ex-Mayor of Sabula.

[5] This point is about ten miles from Muscatine and fifty miles from Fulton making the old course about the same length as the new one. A well at this point, reported by Professor Udden, failed to reach rock at elevation 400 feet A. T.

[6] C. H. GORDON: Geol. of Iowa, Vol. III., 1893, p. 246. A well one-half mile north of Ft. Madison reaches a level about 365 feet A. T. without entering rock. The channel may, therefore, be deeper than that shown by the Ft. Madison wells.

[7] Beck's Artesian Well, Geol. of Iowa, Vol. III., p. 247.

[8] Bridge piers rest on a rock shelf 35–40 feet below low water (G. K. Warren).

[9] Data concerning channel piers furnished by W. S. Lincoln, Chief Engineer of Wabash Railroad, St. Louis, Mo.

slopes near the border of the valley. It certainly should not be assumed that they have entered the deepest part of the channel.

If the borings at the points named reach the lowest part of the channel, we may estimate the rate of descent of the rock floor between St. Paul and St. Louis. Between St. Paul and Sabula, a distance of 274 miles, the descent is only 57 feet or 2½ inches per mile. Between Sabula and Fort Madison, a distance of about 140 miles, the descent is 64 feet or about 5½ inches per mile. Between Fort Madison and East St. Louis, a distance of about 210 miles, the descent is about 80 feet or 4.57 inches per mile. These data indicate much less descent from St. Paul to Sabula than below Sabula. We can hardly suppose that a much deeper portion of the channel occurs opposite Sabula, for the well at this village was sunk in the middle of the valley. It seems probable, therefore, that the valley floor has been slightly warped, so that its altitude at Sabula is higher, or at St. Paul lower, than it was when the stream flowed upon the rock floor. To completely demonstrate such a warping, it will be necessary to make certain that the low altitude at Fort Snelling and St. Paul is not due to local deepening, such as may have been produced by glacial water falls, or by subglacial erosion by water or ice. At Sabula no such agencies could have been operative.

The descent in the rock floor, from Sabula to East St. Louis, is not markedly different from that of the present stream, being 145 feet, where the present stream falls 192 feet. If we reduce the descent of the present stream at the two rapids to the average rate for the river it lessens the difference thirty feet, leaving but seventeen feet difference in a distance of about 350 miles,

[10] Bed of present stream is 380 feet A. T. (G. K. Warren).

[11] Mo. Riv. Com. Rept. for 1890. The low water altitude here given is on the Missouri.

[12] Data concerning depth to rock at bridge piers, furnished by Robert Moore, C. E., St. Louis, Mo.

[13] In new channel (G. K. Warren).

[14] Low water varies from 267–279 feet A. T. (Gannett).

[15] Tertiary clays set in at bed of river and extend nearly to sea level (Reports on Memphis water supply, by J. M. STAFFORD and LAWRENCE JOHNSON, issued by Artesian Water Co. of Memphis).

or but six-tenths of an inch per mile. Under present conditions the river will soon remove the rapids and reduce its rate of fall to that of the rock floor, if not, to a lower rate.

The Missouri Valley.—For purposes of comparison with the Mississippi Valley, and valleys further east we introduce at this point a few statements concerning the Missouri Valley, followed by a table showing the elevation and slope of the valley floor and of the present stream, from Sioux City to the mouth of the stream. The table is compiled chiefly from data given in the annual reports of the Missouri River Commission for 1890 and 1892. We are indebted for additional data to Mr. George S. Morison of Chicago, chief engineer in the construction of several bridges across the Missouri. We are also indebted to Professor J. E. Todd, State Geologist of South Dakota, for suggestions, both published and unpublished, concerning the history of this youthful but somewhat overgrown tributary of the Mississippi.

The researches of Professor Todd and others have developed the fact that the present course of the Missouri, through the Dakotas is independent of preglacial valleys, and dependent upon the position of the ice margin. Its course along the boundary of Nebraska is considered by Professor Todd to antedate but little the late ice invasion which was marked by the Altamont moraine. He finds evidence that Lake Cheyenne persisted, in eastern Nebraska, southeastern Dakota and southwestern Iowa, to the beginning of the glacial period[1] and infers a very low altitude for the region up to that time, one not calculated for deep erosion of valleys. He writes that he has not yet found a clear case along the Missouri Valley, of excavation prior to the glacial deposition. In examinations of the rock surface exposed in sinking the piers of the bridges at Blair and Omaha, he failed to discover evidence of glacial action. Alleged glacial deposits in the valley lower down, as at St. Charles, Missouri, he thinks capable of another interpretation. The entire valley may prove to be more recent than the Kansan stage of glaciation.

[1] Evidence that Lake Cheyenne continued till the Ice Age, by J. E. TODD, Proc. A. A. A. S., Cleveland Meeting, Vol. XXXVII., 1888, pp. 202, 203.

The reports of the Missouri River Commission show, in profile, the results of a series of test borings across the entire breadth of the valley at Sibley, Missouri.[1] The rock floor nowhere stands more than sixty-five feet below low water, or little, if any, below the scour of the present stream. Borings at St. Charles, Missouri, on the very border of the Mississippi Valley, apparently test the rock floor of the Missouri in its lowest part, and find it but seventy feet below low water.[2] Only twenty miles below St. Charles at Bellefontaine, the bridge shows at its north pier a rock floor 107 feet below low water at this point. The rock floor is perhaps still lower between there and the Mississippi channel four miles to the north, there being a slight northward descent in the rock floor at the north pier. The available data seem to indicate that where the Missouri joins the Mississippi, the latter has a channel forty to fifty feet or more deeper than the former.

ALTITUDES OF THE ROCK FLOOR AND PRESENT MISSOURI AT BRIDGES BETWEEN SIOUX CITY, IOWA, AND THE MOUTH OF THE STREAM.[1]

Location	Dist. Miles	Low water A. T.	Fall per mile	Rock Floor, A. T.
		Ft.	In.	Ft.
Sioux City, Iowa	0	1076		950 ±
Blair, Nebraska	102.8	986	10.50	934–944
Omaha, Nebraska	35.5	963	7.77	839–890
Plattsmouth, Nebraska	25.5	943	9.41	872
Nebraska City, Nebraska	25.9	910	15.29	750[2] / 815–855
Rulo, Nebraska,	70.2	843	11.45	715[3]
White Cloud, Kansas	12.1	833	9.90	772
St. Joseph, Missouri	46.4	794 ±	10.08	743
Leavenworth, Kansas	57.2	745	10.28	688 —
Kansas City, Missouri	31.1	721	9.26	660–680
Randolph Bluffs, Missouri	4.0	713	24.00	631
Sibley, Missouri	36.7	690	7.52	625–655
Glasgow, Missouri	102.5	594	10.23	550
Booneville, Missouri	31.7	570	9.08	513
St. Charles, Missouri	177.7	420	10.13	350
Bellefontaine, Missouri	21.7	406 / 402	7.79	295

[1] Report of Missouri River Commission for 1889–90, Appendix XX. of the Annual Report of the Chief of Engineers for 1890, p. 3379, Plates V. and VI., Government Printing Office, Washington.

[2] Loc. cit., p. 3377 and Plates I. and II.

The Illinois Valley.—The data concerning the rock floor from the bend of the Illinois northward, along the preglacial valley are very meager. Professor Chamberlin reports a boring at Lake Koshkonong, Wisconsin, which failed to reach rock at 450 feet. A. T. A boring at Janesville, Wisconsin, enters rock at 530 feet A. T. and several at Rockford, Illinois, at 529–588 feet A. T. But these are all very near the west bluff and, in all probability, enter rock much above the level of the deepest part of the old channel. It is in the portion of the old valley occupied by the Illinois that the rock floor is best known.

We begin the table at the head of the present Illinois, that the contrast between the new and the old valley may be brought out. For the low water altitudes and for the measurement of distances we are indebted to a report of the Chicago Drainage Commission, prepared by Mr. L. E. Cooley, an engineer of that commission. Records of borings showing the elevation of the rock floor have been obtained at the offices of the persons or companies who made them, except in the case of the Princeton artesian well. The record of this well was furnished by Mr. Jacob Miller, President of the Princeton Academy of Science. The Princeton well-boring is here included, since it is near the border of the present Illinois Valley and probably strikes the deepest part of the old channel. We are indebted to Professor J. A. Udden, of Rock Island, for the collection of records of wells at Bureau Junction, Hennepin, Putnam and Henry.

[1] It should be noted that the low water altitudes here given, taken from the report of the Missouri River Commission, average about four feet higher than in Gannett's Dictionary of Altitudes, Bull. U. S. G. S., No. 76. The altitudes given in the table for the Mississippi are from Gannett's Dictionary of Altitudes.

[2] The report of the Missouri River Commission for 1890 contains a description of a gorge 2000 feet or less in width and 60–75 feet in depth, which crosses the valley in an east to west direction, nearly at right angles with its present course.

[3] The river silts and sands extend only to elevation 790 feet. Beneath them is a hard clay seventy-five feet in depth. The description given in the reports of the Missouri Commission do not make clear whether it is a glacial deposit or an earlier formation.

ALTITUDES OF ROCK FLOOR AND PRESENT ILLINOIS.

Location	Dist. Miles	Low water A. T.	Fall per mile	Rock Floor, A. T.
		Ft.	In.	Ft.
Mouth of Kankakee River	0.0	485.3		483 ±
One mile below Kankakee River	1.0	481.6	44.04	479
Head of Marseilles Pool	11.7	477.9	3.80	?
Marseilles Dam	12.7	476.8		468 [1]
Marseilles, below dam		468.8	8.59	456–468
Foot of rapids	1.5	458.3	84.00	457 ±
Above Ottawa ⅔ mile	5.3	447.9	23.54	445
Head of rapids	6.7	444.9	5.37	440
Head of pool	2.6	438.1	31.38	435 ±
Peru, at Zinc Works	7.3	438.1 [2]		
		433.9	6.90	320
Princeton, in buried channel				270
Bureau Junction (Bureau Creek Valley)				340
Hennepin	13.6	438.1 [2]		
		432.2	1.50	380
Putnam, two miles from river				340
Henry				355
Peoria (Bigham's artesian well)	47.4	428.9	0.84	341
Pekin, at City artesian well	10.7	427.3	1.79	325
Beardstown. Artesian wells	63.3	418.6	1.65	345
Mouth of Illinois	86.1	403.6	2.09	?
Bellefontaine, Missouri. Bridge foundation	17.0	402.0 ±		295
East St. Louis, Illinois. Bridge foundation	24.3	380.0		284

The causes for the very low altitudes of the rock floor, and also the slight descent of the present stream below Peru, merit careful consideration, while the irregularities in the rate of descent in the portion above Peru, need a word of explanation.

Taking these up in the reverse order we find the irregular descent above Peru to be plainly attributable to variation in resistance to erosion, presented by the stream bed. The rapids occur where the stream is cutting across hard rock ledges, while the pools occur in the softer strata, between these ledges. This valley, as is well known, once constituted the outlet of Lake Michigan and was then occupied by a stream having much

[1] River raised by dam. The dam rests on rock at 468 feet A. T.

[2] River raised by dam to 438.1 feet. The dam is located at Henry, Illinois, 13½ miles below Hennepin. The altitudes at points below Hennepin are given at the natural level of the river.

greater volume than the present river. This stream effected a great amount of erosion, but its duration was too brief to enable it to cut down its bed in the new portion of the valley, to a uniform slope. Mr. Cooley has well expressed the influence of the strata in his discussion of the old lake outlet:

"The ancient stream carved its grade according to the resisting material, steep in the Niagara limestone to Lake Joliet, steep in the Cincinnati limestone at the mouth of the Kankakee, light through the friable Coal Measures, to the resisting strata at Marseilles, and steep in the St. Peter's sandstone from above Ottawa to Utica, where the water-lime group checked the lakeward extension of the alluvial valley. . . . .

"Below Utica a wide valley in the Coal Measures, narrowing toward the mouth in the resisting rock of the older formations, extends for 230 miles to the Mississippi, with a present fall of about 28 feet (31 feet). The sand and gravel of the ancient stream bed lie deep below the silts and ooze, the spoils of the land through which the comparatively insignificant modern stream struggles to maintain a channel and build up its bed and inadequate grades to present requirements. A wide expanse is there of shallow lakes, bayous, marshes and fens, reed growing lowlands, and low bottoms, which in a true alluvial stream adjusted to its work should be at ordinary extreme high water, but which are but little more than half way there" (Report to Chicago Drainage Commission, p. 2).

Mr. Cooley's words introduce us to a consideration of the cause for the low rate of fall below Peru. If we divide this portion of the valley into small sections, we find interesting contrasts. There is, between Peru and Peoria, a distance of sixty miles, an average fall of one inch per mile. This is distributed as follows:

Peru to Hennepin,	13.6 miles.	Rate of fall, 1.5 inches per mile.
Hennepin to Henry,	13.5 miles.	Rate of fall, 1.07 inches per mile.
Henry to Chillicothe,	13.3 miles.	Rate of fall, .55 inch per mile.
Chillicothe to Peoria,	18.3 miles.	Rate of fall, .26 inch per mile.

From Peoria to Beardstown, a distance of seventy-four miles, the average fall is 1.67 inches and from Beardstown to the mouth, a distance of eighty-six miles, it averages a little more than two inches per mile (2.09). Even this, the most rapid rate shown in the lower Illinois is remarkably small, compared with that of

the Mississippi. The fall in that stream in the 222 miles from the mouth of the Illinois to Cairo, being 133 feet, or about 7.18 inches per mile.[1] We seem to have in the lower Illinois Valley a partially obliterated lake in which the outlet has worked its head up the valley to the vicinity of Peoria, with a decrease in slope headwards. Then comes Peoria Lake, between Peoria and Chillicothe, at the head of which is a silt-filled district, in which the river shows an increase in slope headwards to Peru, the old head of the pool or lake. The only available data concerning the amount of filling is obtained at the Santa Fé bridge at Chillicothe, where it is probably much lighter than nearer the head of the old pool. The bridge foundations are reported to have reached the bottom of the river silts at a depth of thirty feet below the bank, or about twenty feet below the bed, there being coarse sand and gravel at lower depths.[2] A series of test borings along the valley is needed to bring out satisfactorily the condition of the valley bed at the beginning of the present period of deposition.

It is a question whether the lake outlet was adequate to produce a channel with such extremely low grade as this valley presents between Hennepin and its mouth. Another possible factor should be considered, that of a warping of the valley subsequent to this period of excavation.

This leads us to the discussion of the attitude of the floor of the preglacial valley. By reference to the above table it will be observed that the valley floor at Princeton is but 270 feet A. T., while the lowest known point in the valley bottom opposite St. Louis, forty miles below the mouth of the Illinois and 260 miles below Princeton, is 284 feet A. T. or fourteen feet higher than at Princeton. It is barely possible, but scarcely probable, that there exists, opposite St. Louis, a channel sufficiently deep to give a fair gradient for the valley floor from Princeton to St. Louis. A gradient of but three inches to the mile would require a

[1] The distance we have given is about that of the high water stage. COOLEY'S report to the Chicago Drainage Commission gives 238 miles as the distance along the river channel. This would reduce the fall per mile to 6.70 inches.

[2] COOLEY'S Report to Chicago Drainage Commission, p. 58.

channel sixty-five feet deeper opposite St. Louis than is yet known to us. It is doubtful if the lower end of the Illinois Valley has a rock floor as low as at Princeton. Borings in the middle of the valley at Beardstown reach rock at an elevation seventy-five feet higher than the rock floor at Princeton, though nearly 150 miles below Princeton. Several wells have been made in Beardstown, and they indicate a quite uniform level of the rock floor. It is possible, but hardly probable, that a much deeper channel exists at that point. Wells above Beardstown, at Pekin and Peoria, though situated in each case within one-half mile of the rock bluffs, reach a lower elevation than those at Beardstown before entering rock, while at Peru a well which is apparently in a small preglacial tributary of the Illinois, several miles from the main valley, finds the rock surface at a lower elevation than the wells at Beardstown. We may have, therefore, in this valley, a warping of the rock floor to such a degree that the slope has been reversed above Beardstown.

If we compare the elevation of the rock floor in this portion of the Illinois, with that of the Mississippi a few miles to the west, we find support for the view that this section of the Illinois valley is much depressed. The boring at Sabula, Iowa, 65 miles in direct line from Princeton, apparently tests better than any other boring, the limit of excavation in the Mississippi. The Sabula boring shows the rock floor to have an elevation 429 feet A. T., or 159 feet above that at Princeton. In case the upper Mississippi Valley connected with the valley at Princeton, through the Green river basin, its valley floor would have a fall of nearly 2½ feet per mile, or six times the rate of fall of the present upper Mississippi, and nearly thirty times the fall of the present Illinois just below Princeton.

About 150 miles further down we find no evidence that the Illinois and Mississippi differ greatly in the elevation of their valley floors. Thus wells at Ft. Madison, on the Mississippi, and at Beardstown, on the Illinois, separated by a distance of about 60 miles, and in the same relative position as the Sabula and Princeton borings, show only 20 feet difference in the altitude of the rock floor.

The available data seem, therefore, to point quite strongly to a depression in the portion of the Illinois valley north from Beardstown. To fully establish this depression, it will be necessary to make certain that there is no narrow gorge leading down the Illinois, with a rock floor sufficiently low to correspond with that at Princeton. If the absence of such a gorge were demonstrated by a full series of test borings across the valley at points below Princeton, there would still remain an element of uncertainty in the fact that a local deepening of the valley through glacial agencies may have been produced at Princeton during the ice invasion. We would remark, however, that the valley has a trend transverse to the direction of ice-movement and, therefore, unfavorable for erosion by the ice, or by subglacial streams.

The probability of northward depression in the Illinois valley being so strong, we will refer briefly to a possible cause for such a depression. To the general cause for northward depression, found in the weight of the ice-sheet, we have here an additional cause in the immense amount of drift deposited along the course of the old valley. This valley, from the vicinity of Pekin northward, past Princeton, is bordered by a very bulky moraine, which, for some distance northward from Princeton occupies the supposed old course of the Rock-Illinois. The drift in this region is rarely less than 200 feet, and probably reaches a depth of between 500 and 600 feet north of Princeton, where the moraine occupies the old valley. This weight, unlike the ice-sheet, still continues an obstacle to the return of the valley floor to its former altitude, if not as a direct cause of depression. It may be found that some depression has been produced by it since the date of the lake outlet. If so the very low gradient of this portion of the Illinois would be explained only in part by the greater volume of the lake outlet. Recent warping of the valley may become an important factor.

The Wabash Valley.—The few borings of which we have record along the Wabash below Covington, are situated in the middle of the valley and probably test its deepest portion. The altitudes of the valley floor and present stream at points where these borings have been made are as follows:

	Present Stream	Valley Floor
Montezuma, Artesian well -	465 ± ft.	400 ft
Clinton, Coal boring - -	450 ± "	370 "
Terre Haute, Oil wells -	445 ± "	345–360 ft.
Vincennes, Artesian well -	400 ± "	345 ft. ±
Shawneetown, Ill., Oil boring -	350 ± "	240 "

The altitude of the valley floor of the Wabash is apparently somewhat higher than that of the Illinois and Mississippi valleys in the same latitude, the difference in altitude is, however, not very marked.

In the district north from the bend of the Wabash at Covington several borings have been made which show a rock floor lower than those on the Wabash. One boring near Oxford, Indiana, enters rock at the extremely low elevation of 300 feet A. T. A few miles northwest from Oxford, in Iroquois county, Illinois, a boring is said to have reached a depth of 400 feet without entering hard rock. As its mouth is but 660 feet the rock floor here may fall below 260 feet A. T.[1] Unfortunately this record is not so trustworthy as the importance of the determinations of so low an altitude of rock floor would demand. The exact depth is somewhat uncertain and there is a possibility that the soft Cincinnati shales may have been entered near the base and not distinguished from the blue till of the overlying drift. The records of the Oxford borings are apparently trustworthy. The region north from Covington, Indiana, may present such a northward depression, as is exhibited by the portion of the Illinois near Princeton.

A few borings in the east central part of Illinois, nearly midway between the Wabash and Illinois, show a remarkably low rock surface. These may be in the line of a valley discharging southward to the Kaskaskia, or in tributaries of the Wabash or of the Illinois. A well at Monticello, in Piatt county, Illinois, reached a level but 352 A. T. without entering rock. One at Kenney, in western De Witt county, failed to find rock at 358 feet A. T. A boring made at Paxton, in Ford county, entered rock at 350 feet A. T., while one at Odell, in Livingston county, entered rock at 355 feet A. T. It appears from these data that

[1] Geol. of Illinois, Vol. IV. p. 237.

the preglacial channels of east-central Illinois have a sufficiently low depth to correspond with the low altitude at Princeton or at Oxford. These borings which show so low a rock floor all occur in a district very heavily covered with drift. The cause suggested for the low altitude at Princeton may find application in the entire field of heavy drift between Princeton and Oxford.

The Lake Michigan basin and outlet.—It is yet to be determined whether the Lake Michigan basin is connected on the south with a preglacial tributary of the Mississippi by a channel so low even as the floor of the Oxford borings. We have already noted that the most probable line for such a connection would be southward from Michigan city to the Wabash, near La Fayette, and thence west to Oxford. But the lowest altitudes found along this line, north from La Fayette, are much above that of the rock floor at the Oxford boring. The boring at Monticello, Indiana, enters rock at 467 feet A. T., that at Winamac at 490 feet and that at North Judson at 497 feet. The lowest altitude yet found near the border of the southern portion of the Lake Michigan basin is 350 feet A. T.

A line following the longer axis of the basin descends from 350 feet at Michigan city to about sea level opposite Racine, then rises above 200 feet A. T. opposite Milwaukee, north from which it descends to 289 feet below sea level, and continues below sea level nearly to the north end of the lake. As the lake bottom is probably coated to considerable depth with glacial deposits and lake sediments, the rock floor will show even greater range.

Cross sections of the basin show interesting variations. In the deep portion of the basin opposite Racine there is very little irregularity. The bottom is as smooth as it is in the southern end where the drift has concealed all the irregularities of the rock floor. East from Milwaukee the lake charts show a single narrow ridge in an otherwise smooth bottom. Between Port Washington, Wisconsin, and Muskegon, Michigan, a cross section presents the appearance of a series of escarpments facing westward like the Niagara escarpment of eastern Wisconsin. The highest points exceed 300 feet A. T. For some distance

north of this line only slight irregularities of bottom appear. But the north end of the basin is very irregular in depth.

The low altitudes of the rock floor in northeastern Illinois and northwestern Indiana seem readily accounted for by a differential crust movement without the aid of glacial erosion. But in producing the variations in altitude displayed by the floor of the Lake Michigan basin glacial erosion was probably an important agency. With fuller light concerning the floors of the great valleys parallel with the lake basin there will probably be developed criteria for estimating, more accurately than is now possible, the effect of each agency which has been influential in the shaping of the lake basin.

The Ohio Valley.—Concerning this great eastern tributary of the Mississippi we have space for but a few remarks.

The lower portion of the Ohio valley has received, as yet, very little attention and we have data concerning the altitude of the rock floor at but one point below Lawrenceburg, Indiana, viz, Shawneetown, Illinois, where it is 65 feet below the present stream. At Lawrenceburg, Indiana, and Cincinnati, Ohio, the rock floor is but 50 to 75 feet below low water, or but little below the scour of the present stream. Above these points, so far as ascertained, the rock floor is usually within 30 to 60 feet of the present stream bed until we reach the upper Allegheny, when it drops down rapidly and leads through buried channels to the Lake Erie basin. The northern tributaries of the Ohio, being as a rule deeply filled with drift, are now flowing at considerable heights above the rock floor. The present streams show a much more rapid descent than the rock floors, even where the rock floors slope toward the Ohio. In the headwater portions of these south-flowing tributaries, the rock floor has been found in several instances to slope northward. This fact, together with the occurrence of deeply filled channels, leading across the present watershed, is thought to indicate that the drainage basin of the Ohio has been greatly enlarged, through the influence of the glacial invasions and deposits within the state of Ohio, as well as in Pennsylvania and western New York.

The depth of *preglacial* erosion in the upper Ohio region is a

subject upon which differences of opinion have arisen among the several geologists who have investigated the region; it being maintained by some, among whom the present writer is included, that in consequence of the enlargement of the drainage area by a glacial invasion, a considerable part of the valley has been deepened below the limits of the preglacial rock floor. Others maintain that the deepening occurred shortly before the first ice invasion, during a supposed brief period of higher elevation than the present and is therefore *preglacial*. We can only refer the reader to the literature of this subject as presented by Carll, White, Stephenson and Chance, in the reports of the Pennsylvania Geological Survey, and more recently by Chamberlin, Wright, Foshay, Hise and Leverett, in the *American Journal of Science*.

Reviewing the data of the entire field we find that the valley floors of the Mississippi, Illinois and Wabash were excavated, prior to the first ice invasion, to a depth 50 to 200 feet below the present streams. The southern portion of these valley floors apparently slope southward, with a gradient not greatly different from that of the present streams, while the northern portions are considerably depressed. It seems probable, therefore, that the north part of the Mississippi basin stood relatively, if not absolutely, higher than now prior to the first ice invasion. The portion near the southern border of the glaciated district may have stood no higher than at present. The region drained by the Missouri, on the other hand, seems to have had, up to the time of the first ice invasion, a lower altitude than the present. There seems, on the whole, little evidence that much of the Ohio drainage basin has stood higher. The complications in this valley, resulting from the great increase of the size of the drainage basin, make it difficult to estimate the preglacial altitude, for the enlarged stream would require, independent of altitude, a deeper valley.

AGE AND STAGE OF DEVELOPMENT OF THE PREGLACIAL VALLEYS.

In closing this discussion a few remarks seem necessary concerning the date of the uplift which inaugurated the channeling

of the preglacial valleys and the stage of development which these valleys had reached when the ice invasion occurred.

The study of physiographic development carried on in the eastern part of the United States through the zealous labors of Davis, McGee and others has brought to light a strong array of evidence indicating that the valley channeling of the region under discussion was not begun until after the close of the Cretaceous, and that it may have been largely accomplished in the latter part of the Tertiary.

It is evident from the sharply outlined valley borders, and other reliefs of the region, that the drainage systems had not reached a stage of senescence, though the size of the valleys, or the the measure of work which the preglacial streams accomplished, is certainly several times as great as that of the post-glacial valleys. The preglacial valleys are not only deeper than the present valleys, but were also excavated, as a rule, in a more resistant material. The accompanying figure, furnished through the kindness of the state geologist of Iowa, serves to show the

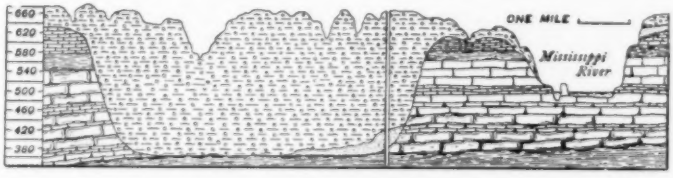


FIG. 1. Cross-section from Sonora, Illinois, to Argyle, Iowa, showing old and new channels of the Mississippi River. [Iowa Geological Survey.]

comparative sizes of old and new channels when cut in material of the same degree of resistance. It would apply equally well in other large valleys of this region, situated outside the limits of the later ice invasion. Within the limits of that invasion, the post-glacial valleys are much smaller than in the older drift territory. Where the present stream follows the preglacial channel in the older drift territory, it has usually removed the glacial deposits throughout the entire breadth of the preglacial valley, leaving only the portion of these deposits that lies below

the level of its scour. The contrast in size of preglacial and present valleys in such cases is not great, though the work accomplished in removing the glacial deposits is no greater than in cutting the narrower valley in the rock, shown in the figure.

In places a preglacial valley is found to carry shelves of considerable breadth, now concealed beneath the present valley bottom, thus at Quincy and St. Louis a rock shelf extends entirely across the present bed of the Mississippi, with an altitude 60 feet or more above the deeper portion of the valley. The following tabular statement of data of the two bridges in St. Louis, furnished by Robert Moore, C.E., serves to show the existence of such a shelf at one bridge and its absence at the other. The Eads bridge is about three miles below the Merchant's bridge. Its west end is at the west bluff, while the west end of the Merchant's bridge is one-half mile from the west bluff. The shelf, therefore, extends at least one-half mile further into the valley than the length of the bridge.

ELEVATIONS OF ROCK FLOOR AT ST. LOUIS BRIDGES.

	Eads Bridge	Merchant's Bridge
Bed Rock Pier 1, West Shore	375.71 feet	341.33 feet
Bed Rock Pier 2	341.91 "	342.05 "
Bed Rock Pier 3	293.71 "	339.93 "
Bed Rock Pier 4, East Shore	284.30 "	334.90 "
Extreme high water	420.29 "	422 (?) "
Extreme low water	378.97 "	380.50 "

It is probable that such shelves as these are remnants of an old valley floor. Their full breadth is not known, hence we cannot judge whether they are mere fringes on the border of the deep channel, or are of such breadth as to reduce greatly the width of the deep channel. The data from the St. Louis bridges cover only about one-tenth, while those of the Quincy bridge cover one-sixth the breadth of the preglacial valley. If the shelves greatly reduce the width of the valley, their bearing upon the valley's history—its stages of uplift, etc.—may prove to be of considerable importance. It is as yet not certain whether the valley was deepened regularly during continuous

uplift, or whether it was subject to periods of deepening, between which were periods of equilibrium, when the force of the stream was expended in broadening the channel.

An important feature connected with the development of the preglacial drainage of this region has received thus far but little attention, namely, *variations in stage of development* displayed by the drainage lines in different parts of the Mississippi basin. My attention was first called to the matter when studying southern Illinois, in the autumn of 1892. It was found that there is a great scarcity of deep buried valleys, compared with their number further north. It is only at rare intervals that a well on the uplands fails to strike rock within a few feet of the level of the upland plain. The main preglacial valleys of this region are cut to but moderate depths, seldom showing an excavation of more than 100 feet below border districts. Upon discussing this matter with Professor Chamberlin it was found that he had noted a similar feature in the unglaciated part of Missouri, near Sedalia. The greater part of the surface is unfurrowed by drainage lines. The few which occur have reached only an adolescent stage of development. The appearance is as if an uplifted base leveled region had been subjected to erosion for an insufficient time to allow well developed systems of drainage to be inaugurated. Further north (and especially in northern Illinois and the driftless area of Wisconsin) the preglacial systems had dissected the uplands quite thoroughly. though the altitude is not much greater than southern Illinois and scarcely so great as the region around Sedalia. From what is now known, it seems probable that the northern districts suffered uplift long before the southern. A thorough investigation of this matter will doubtless bring out a very interesting history, showing an increasing extent and degree of uplift proceeding from certain centers of upheaval, by which the peneplain of the Cretaceous and early Tertiary periods rose and became transformed into the more or less deeply channeled uplands of the early Pleistocene.

FRANK LEVERETT.

Denmark, Iowa, May 23, 1895.

THE CLASSIFICATION OF THE UPPER PALÆOZOIC ROCKS OF CENTRAL KANSAS.[1]

[Continued from Vol. III., No. 6.]

THE NEOSHO FORMATION.

Between the Cottonwood formation and the base of the first massive limestone, containing an abundance of flint in layers, is a series of gray limestones alternating with various colored shales, some of which are yellowish-gray in color, corresponding in lithological appearance, and containing a fauna similar to the Cottonwood shales, while others are olive and reddish in tint and non-fossiliferous. Interstratified are shaly limestones and dark gray hard limestones which contain an abundant Lamellibranch fauna. Numerous exposures of this formation occur in Chase county along the Cottonwood and its branches, and also to the northeast in the Neosho valley in Morris county. On account of the excellent exposures of this formation in the Neosho valley and its tributaries extending from three miles northwest to six miles southeast of Council Grove it is proposed to call this mass of rocks the *Neosho formation.* In the vicinity of Council Grove there are good exposures in the steep hills near the city and especially along Elm and Four Mile Creeks, which are western branches of the Neosho River south of Council Grove.

Geologic section of the Neosho formation.—In Chase county there are good exposures of this formation at the following localities: on "Crusher Quarry Hill," one and one-half miles west of Strong City; on the western side of the Cottonwood River opposite and above Clements; on Buckeye Creek, south of Cottonwood Falls; on Rock Creek, west of Bazaar; and on South Fork of the Cottonwood River, near Matfield Green. The Crusher Quarry Hill affords a good section of this formation; the Cotton-

[1] Published by permission of the Director of the United States Geological Survey.

wood limestone appears at the foot of the hill, near railroad level, while the first heavy stratum of flint and limestone of the so-called "Flint Hills" forms the brow of the bluff. The following section of the exposures on the slope and along the road up to the Crusher Quarry gives quite accurately the thickness of the various strata composing this formation:

		Feet.	Feet.
No. 20.	Soil at top of bluff - - - - - - -	2 =	168
" 19.	Massive light gray limestone - - - - containing an abundance of flint. The stratum quarried for the railroad crusher.	19 =	166
" 18.	Yellowish shaly limestone - - - - -	2½ =	147
" 17.	Light gray limestone - - - - - - with an abundance of flint. The base of the first heavy flint limestone.	1½ =	144½
" 16.	At top fine yellowish shales - - - - with Cottonwood shale fauna; the lower shale are coarser.	23 =	143
" 15.	Massive limestone - - - - - - - in some places 4 feet thick and quarried. Near Council Grove limestone, from 25–30 feet, below the base of the flint, containing *Pleurophorus*, and above the limestone are ferns.	3 ± =	120
" 14.	Mainly yellowish shales - - - - - - some greenish with thin, shaly limestones.	36 =	117
" 13.	At top limestone with *Pseudomonotis* - - 2′ 10″ in thickness; one layer of the limestone contains an abundance of small iron concretions. Below are shales.	10⅔ =	81
" 12.	Light gray limestone - - - - - - containing *Pseudomonotis*.	1⅓ =	70⅓
" 11.	Green and chocolate colored shales - -	20 =	69
" 10.	Light gray, shaly limestones- - - - - containing *Pseudomonotis* and other fossils.	4 =	49
" 9.	Shales, about 4′ or more in thickness - -	4 =	45
" 8.	Dark gray silicious limestone - - - on weathered surface, very irregular with rough jagged prominences.	2 ± =	41
" 7.	Yellowish shales - - - - - - - - argillaceous containing some of the Cottonwood shale fauna.	6 =	39

" 6.	Yellowish blocky shales - - - - - - containing a Lamellibranch fauna of *Pseudomonotis* and *Aviculopecten*, which in places appear to form a massive rough limestone similar to No. 8.	5	=	33
" 5.	Greenish shales - - - - - - -	7	=	28
" 4.	Chocolate and drab shales - - - -	4	=	21
" 3.	Shaly limestones - - - - - - -	4	=	17
" 2.	Yellowish shales - - - - - with abundant fossils in the lower part. *Cottonwood shales.*	13	=	13
" 1.	*Cottonwood limestone* - - - - - exposed just above railroad switch, 2[1] +.			0

In the above section, the beds from No. 3 to No. 16, inclusive, with a total thickness of 130 feet are regarded as forming the *Neosho formation*. Stratum No. 8 which weathers to a very rough jagged surface, is somewhat similar in lithologic appearance to the "dry bone limestone" in the upper part of the Wabaunsee formation. This limestone has usually been considered magnesian,[2] but the chemical analysis reveals only a trace of magnesia, and to the presence of silica may be ascribed its roughness.[3]

Palæontology. — As described in the above section, the Neosho formation contains green, chocolate and yellow shales, and as the yellow shales approach the lithologic conditions of the Cottonwood, they frequently contain some of the Cottonwood fossils. No. 7 is one illustration of this statement, and the top of

[1] The thickness and lithologic characters of Nos. 3 to 7, inclusive, were obtained in part from the section at the east end of second railroad cut west of Crusher Hill. In the measurement of the lower part of the section I was assisted by Professor Erasmus Haworth of the University of Kansas.

[2] See Prel. Rept. Geol. Surv. Kans. p. 15, where No. 78 of Swallow, a "gray and drab porous limestone, 2 feet," 38 feet above the Cottonwood is evidently this stratum.

[3] The following analysis is by Mr. Warren Finney:

SiO_2 - - - -	15.99	per cent.
$CaCO_3$ - - - - -	77.65	"
Al_2O_3 - - - -	4.50	"
Fe_2O_3 - - - - -	1.03	"
$MgCO_3$ - - - -	trace	
	99.17	"
CO_2 - - - - -	38.75	"

No. 16, at the summit of the formation just below the lowest stratum of massive limestone and flint, is another.

In the yellow shales of No. 7, exposed in the second railroad cut west of Crusher Quarry Hill, the following species were collected:

1. *Chonetes granulifera*, Owen. (a)
2. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. = *A. argentea*, (Shep.) Keyes. (rr)
3. *Productus semireticulatus*, (Martin) de Koninck. (c)
4. *Derbya crassa*, (M. and H.) H. and C. (rr)
5. *Meekella striato-costata*, (Cox) White and St. John. (rr)
6. *Rhombopora lepidodendroides*, Meek. (a)
7. *Septopora biserialis*, (Swallow) Waagen. (rr)

In No. 16, immediately below the base of the flint at the brow of Crusher Hill, the following species were obtained:

1. *Chonetes granulifera*, Owen. (c)
2. *Derbya crassa*, (M. and H.) H. and C. (r)
3. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. = *A. argentea*, (Shep.) Keyes. (rr)
4. *Productus* sp. (rr)
5. *Crinoid* stems. (r)

Certain layers of the coarser shales and limestones of this formation contain a fauna composed largely of Lamellibranchs, and from the yellowish blocky shales of No. 6, in the railroad cut west of Craik's Creek and Crusher Hill, the following species were collected:

1. *Aviculopecten occidentalis*, (Shum) Meek and Worth. (c)
2. *Pseudomonotis Hawni*, (Meek and Hayden). (c)
3. *Meekella striato-costata*, (Cox) White and St. John. (c)
4. *Pseudomonotis Hawni*, (M. and H.), var. *ovata* M. and H. (rr)
5. *Pinna peracuta* Shum. (?) (rr)
6. *Pleurophorus* cf. *oblongus*, Meek. (rr)
7. *Derbya crassa*, (M. and H.) Hall and Clarke. (rr)
8. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. (rr)
9. *Productus semirecticulatus*, (Martin) de Koninck. (r)
10. *Chætetes* cf. *carbonarius*, Worth. (rr)

11. *Spirorbis* sp. (r)
12. Cf. *Aclis robusta*, Stevens. (r)

In the light gray shaly limestones as exposed on the road up the Crusher Hill — No. 10 of the section — are the following species:

1. *Productus nebracensis*, Owen. (aa)
2. *Aviculopecten occidentalis*, (Shum.) Meek and Worth. (a)
3. *Pseudomonotis Hawni*, (Meek and Hayden). (a)
4. *Pleurophorus subcostatus*, Meek and Worth. (c.)
5. *Myalina perattenuata*, M. and H. (r)
6. *Myalina kansasensis*, Shum. (rr)
7. *Meekella striato-costata*, (Cox) White and St. John. (rr)
8. *Derbya* cf. *crassa*, (M. and H.) Hall and Clarke. (rr)
9. Cf. *Aclis Swalloviana*, (Gein.) Meek. (c)
10. *Spirorbis* sp. (c)
11. *Edmondia* sp. (rr)
12. *Bellerophon* sp. (rr)
13. *Discina* sp. (rr)
14. *Zaphrentis* sp. (rr)

On the banks of the South Fork of the Cottonwood River at Matfield Green, and by the roadside three-fourths of a mile north of the village are good exposures of a very hard dark gray to bluish shaly limestone. The presence of an abundance of a few species of fossils in this limestone has been noted at various localities and thus forms a characteristic feature of the formation. This horizon belongs, probably, to No. 12 or 13 of the Crusher Hill section, and at Matfield Green is the following fauna:

1. *Pleurophorus subcostatus*, Meek and Worth. (a)
2. *Productus nebrascensis*, Owen. (a)
3. *Aviculopecten occidentalis*, (Shum.) Meek and Worth. (a)
4. *Pseudomonotis Hawni*, (M. and H.) (c)
5. *Pseudomonotis Hawni*, (M. and H. var. *ovata*, M. and H. (c)
6. *Bellerophon* cf. *sublævis*, Hall, or *Urii*, Fleming. (a)
7. Small *Gastropod* cf. *Aclis* sp. (see fig. in Dana's Manual of Geology, Fourth Ed., p. 685, f. 1121). (c)
8 *Myalina* (?) *Swallovi*, McChesney. (c)
9 *Edmondia* cf. *nebrascensis*, (Geinitz) Meek. (r)

10. *Myalina kansasensis*, Shum. (rr)
11. *Myalina perattenuata*, M. and H. (rr)
12. *Pinna peracuta*, Shum. (rr)
13. *Bellerophon* cf. *Montfortianus*, N. and P. (rr)
14. *Allorisma* cf. *subcuneata*, M. and H. (rr)
15. *Schizodus* cf. *curtiforme*, Walcott. (rr)
16. *Macrochilina angulifera*, White (?) (r)

It will be seen from the above faunas that in this formation we have strata containing Carboniferous fossils only, alternating with strata containing a mixture of Carboniferous and Permian fossils. The yellowish shales with abundant specimens of *Chonetes granulifera*, Owen, contain only Carboniferous fossils, while the blocky shales and dark gray limestones contain such species as *Pseudomonotis Hawni*, Meek and Hayden, *Pleurophorus subcostatus*, M. and Worth., etc., which are usually considered characteristic of the Permian or Upper Carboniferous. On account of the predominance of the strata containing this mixed fauna it seems advisable to consider the Neosho as the lowest formation of the division generally called the Permo-Carboniferous. This classification would not differ greatly from that of Meek and Hayden, as defined in 1867 by Dr. Hayden when he stated that "Meek and Hayden regarded the beds . . . . . down so far as to include most, if not nearly all, of Professor Swallow's Lower Permian, as an intermediate connecting series between the Permian and Coal Measures, which, if worthy of a distinct name at all from the latter, should be called Permo-Carboniferous."[1]

[1] Am. Jour. Science, 2d series Vol. XLIV., p. 37. It will be remembered that Swallow called the "dry bone limestone" the base of his Lower Permian, which is about 62 feet below the base of the Neosho formation; and Meek and Hayden did not indicate a precise line of division. Some geologists consider that Meek in his Report on the Palæontology of Eastern Nebraska referred the Permo-Carboniferous and Permian of Kansas to the Carboniferous; but the writer understands that classification to apply only to Nebraska, for Meek said: "All of these strata under consideration along the Missouri . . . . . really belong entirely to the true Coal Measures; unless the division C, at Nebraska City, and some apparently higher beds below there on the Missouri, may possibly belong to the horizon of an intermediate series between the Permian and Carboniferous, for which, in Kansas, Dr. Hayden and the writer proposed the name Permo-Carboniferous" (Final Rept. U. S. Geol. Surv. Neb. and adjg. Territories, 1872, p. 130).

Comparison of the Neosho formation with Swallow's section.—The Neosho formation includes the upper 25 feet of bed No. 79 of Swallow's section and extends to the base of No. 62—the "fifth *cherty limestone*."[1]

These beds all belong in Swallow's Lower Permian, and he gave the thickness as ranging from 111 feet 7 inches to 148 feet 7 inches. Swallow's bed No. 76, which he described as a "soft blue and gray coralline limestone, 3 feet, containing *Monotis Halli*, and *Americana*, *Productus Norwoodi*, *Synocladia biserialis*, *Thamniscus dubius* (?), *Edmondia Hardni*, *Phillipsia Cliftonensis*,"[2] 49 feet above the top of the *Fusulina* limestone, is clearly No. 10 of our section, 45 feet above the Cottonwood limestone. Again, bed No. 68 of Swallow, described as a "hard blue and buff magnesian limestone, containing numerous Permian *Acephala*" from 72 feet 7 inches to 77 feet 7 inches above the *Fusulina* limestone, is probably No. 12 of the Crusher Hill section. Six feet above this limestone Swallow noted a "light buff and drab argillo-magnesian limestone"—No. 66—containing "*Monotis* and *Bakevellia*," and the limestone noted at the top of our No. 13, eight feet above No. 12, probably belongs to the lower part of Swallow's bed No. 66. The limestone—No. 64 of Swallow—is near the horizon of our No. 15, and below the cherty limestone. Swallow described shales containing "*Synocladia biserialis*, *Productus Norwoodi*, *Orthisina Shumardiana*," which are the same as the shales with the Cottonwood fauna called No. 16 of the Crusher Hill section. It will be seen that there is a close agreement between the thickness and lithological characters of the section west of Strong City and the beds of Swallow's section, the upper ones of which he described from exposures near Fort Riley on the Kansas River.

Comparison with Meek and Hayden.—The Neosho formation on the Kansas River includes the upper 22 feet of Meek and Hayden's No. 23 and terminates at the base of their No. 18, to which Meek and Hayden assigned a thickness of 96 feet.[3] Below

[1] Prel. Rept. Geol. Surv. Kans., pp. 14–16.

[2] Ibid., p. 15.

[3] Proc. Acad. Sci. Phil., Vol. XI., p. 17.

Fort Riley, Meek and Hayden did not find continuous exposures, therefore they underestimated the thickness of the rocks between the Manhattan limestone[1] and the base of the lower flint at Fort Riley. They noted at Fort Riley, however, the shales just below the lower flint with the Cottonwood fossils, and they state that No. 19 "contains near the upper part fragments of Crinoid columns, *Synocladia biserialis*, *Spirigera*, *Productus Norwoodi*, *Chonetes mucronata* [*C. granulifera*], *Orthisina Shumardiana*, *Orthisina umbraculum*, etc., with teeth of *Petalodus Alleghaniensis*."[2]

These yellowish fossiliferous shales, which represent No. 16 of the Crusher Hill section, are well exposed below the massive limestone and flint stratum at the Quartermaster's Bridge at Fort Riley.

THE CHASE FORMATION.

Succeeding the Neosho formation are massive limestones and flints separated by beds of variously colored shales which form the region known as the "Flint Hills" of Kansas.

Topographically this is a conspicuous region. Steep hills and bluffs capped by layers of heavy limestone and flint form quite extensive plateaus in which the streams have eroded deep and narrow valleys. Professor Broadhead said this region "might appropriately be termed the Permian mountains."[3]

Three flint horizons.—The formation contains three prominent massive limestones with interstratified layers of flint which cap the conspicuous bluffs and produce the characteristic topographic features of the country. These flinty limestones and the interstratified shales, which are 265 feet in thickness, cover the greater part of the western half of Chase county and are well exposed in bluffs along the Cottonwood River and its tributaries. The name *Chase* is therefore considered appropriate for this formation.

In the Cottonwood Valley the lowest of these limestones and flints caps the Crusher Hill west of Strong City, and for convenience in describing the formation this horizon may be called

[1] Manhattan limestone is the local name of the Cottonwood stone in the Kansas River valley.

[2] Ibid., p. 17.

[3] Trans. St. Louis Acad. Sci., Vol. IV., Pt. III., p. 484.

the *Strong flint*, which varies in thickness from 35 to 45 feet From 110 to 115 feet above the base of the Strong flint is the base of the second massive flint with a heavy limestone above. The horizon is well exposed along the McPherson branch of the A., T. & S. F. R. R., and in the Jones' quarries from one to two miles northeast of Florence. This may be called the *Florence flint and limestone*. The flint strata are 22 feet thick and are separated near the center by a white cellular limestone from one to two feet thick, while above the flint are 40 feet of buff limestone, the lower and upper portions of which are generally more or less shaly, with a massive ledge forming the central portion. The highest flint and limestone is well exposed along the bluffs of the river and small streams near Marion, and its base is about 123 feet above the base of the Florence flint. Near Marion at the base of the flint horizon is a flinty limestone about 4 feet thick, followed by 13 feet of yellowish shales, capped by a zone 10 feet thick, composed of two strata of limestone separated by shales, the limestones containing large irregular concretions which weather to a brown color. The flint is not as uniform in occurrence as in the Florence and Strong flints, so at some localities this horizon is represented simply by a prominent light gray limestone nearly free from flint, and occasionally the particles in the concretionary limestone are small and inconspicuous. As a rule, however, the concretions are large and the stratum may be readily traced across the country either from its exposure in bluffs or streams, or from the line of loose brown concretions crossing the prairie. This limestone has been traced by the writer along its line of outcrop from the center part of Butler county across Chase and Marion counties into Morris county.

This flint and concretionary limestone is the highest prominent flint ledge in the upper Palæozoic of Kansas. It forms a marked stratigraphic horizon that is of great assistance in determining the areal geology of eastern central Kansas, and on account of the good exposures of this zone near Marion City, the horizon has been called the *Marion flint and concretionary limestone*.

General geologic section of the Chase formation.—From the

comparison of a large number of individual sections has been prepared the following general section which gives the thickness and lithologic character of the various strata composing the Chase formation.

			Feet.		Feet.
No. 20.	Massive limestone containing large flint concretions which weather brown and contain *Productus* and a few other fossils. It is composed of two layers separated by a thin shale, *Marion concretionary limestone.*		10	=	265
" 19.	Yellowish shales containing a few *Brachiopods.*		13 +	=	255
" 18.	Light gray limestone generally containing flint. *Marion flint.*		4	=	242
" 17.	Yellowish, chocolate and greenish shales with occasional layers of thin limestone.		62 ±	=	238
" 16.	Buff shaly limestones containing *Lamellibranch* fauna.		22	=	176
" 15.	Massive buff limestone. *Florence limestone*		5 +	=	154
" 14.	Buff shaly limestone containing an abundant *Brachiopod* fauna.		15	=	149
" 13.	Massive limestone with layers of flint.	*Florence flint*	10	=	134
" 12.	White cellular limestone		2	=	124
" 11.	Massive limestone with layers of flint.		10	=	122
" 10.	Yellowish, chocolate and greenish shales		31	=	112
" 9.	Light gray limestone containing an abundance of small *Lamellibranchia.*		2 ±	=	81
" 8.	Shales not well exposed		12 ±	=	79
" 7.	Shaly buff limestones containing large *Brachiopods;* sometimes a massive limestone.		10 ±	=	67
" 6.	Shales, not well exposed		15 ±	=	57
" 5.	Massive gray limestone	*Strong flint.*	3 ±	=	42
" 4.	Limestone with an abundance of coarse flint and some large brown concretions		10 (?)	=	39
" 3.	Yellowish and rather coarse shale		3½	=	29
" 2.	Massive light gray to whitish limestones containing some flint		18	=	25½
" 1.	Light gray limestone with plenty of flint in regular layers.[1]		7½	=	7½

[1] The several beds of the above section are described mainly from exposures near the following localities: Marion concretionary limestone and flint near Marion and Burns; shales of No. 17, east of Cedar Creek near Wonsevu, Chase county; Florence limestones and flint near Florence and Ft. Riley; shales of No. 10, on Middle Creek above Elk, Chase county; Lamellibranch limestone, No. 9, near Four Mile and Six Mile Creeks in the southern part of Morris county; shales and shaly buff limestones of Nos. 6–8 near Cedar Point, Cottonwood Falls and Matfield Green; and the complete series of the Strong flint two miles northeast of Council Grove.

Palæontology.—Certain beds of the Chase formation contain numerous fossils which may be divided into two faunas; one composed principally of large Brachiopods and the other of small Lamellibranchia.

The different layers of the Strong flint are sparingly fossiliferous; and at no locality has any considerable number of specimens been obtained. The following species have been noted:

1. *Enteletes hemiplicatus*, (Hall) H. and C.
2. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb.
3. *Chonetes granulifera*, Owen.
4. *Meekella striato-costata*, (Cox) White and St. John.
5. *Productus nebrascensis*, Owen.
6. *Derbya crassa*, (M. and H.) H. and C. (?)
7. *Pseudomonotis Hawni*, (M. and H.)
8. (?) *Glauconome*, sp.
9. *Echinoid* spine.
10. *Bryozoan* sp.[1]

In the upper part of the Strong flint on the south side of Elm Creek, about three miles west of Council Grove is a very fossiliferous stratum. It is a shaly bluish limestone which probably belongs in No. 3 or the lower part of No. 4 of the Chase formation. The following species were collected at this locality:

1. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. (aa)
   = *A. argentea*, (Shep.) Keyes.
2. *Derbya crassa*, (M. and H.) H. and C. (a)
3. *Derbya multistriata*, (M. and H.) Prosser. (c)
4. *Productus nebrascensis*, Owen. (c)
5. *Pseudomonotis Hawni*, M. and H. (c)
6. *Aviculopecten occidentalis*, (Shum.) Meek (c)
7. *Rhombopora lepidodendroides*, Meek (a)
8. *Aviculopecten McCoyi*, M. and H. (rr)
9. *Septopora biserialis*, (Swallow) Waagen. (c)
10. *Fenestella Shumardi*, Prout. (a)
11. *Myalina perattenuata*, M. and H. (rr)
12. *Myalina recurvirostris*, M. and W. (?) (rr)

[1] These species were collected at the quarry on the Crusher Hill, west of Strong City and from the high hill two miles east of Alma.

13. *Macrodon sangamonensis*, Worth. (?) (rr)
14. *Phillipsia*, sp. (rr)

In the shaly limestones of No. 7 a few species of large Brachiopods were obtained. West of the Dunlap schoolhouse, two miles north of Matfield Green, the following species were collected:

1. *Derbya multistriata*, (M. and H.) Prosser.[1]
2. *Aviculopecten occidentalis*, (Shum.) Meek (rr)
3. *Myalina recurvirostris*, Meek and Worth (?) (rr)
   shells poorly preserved.
4. *Myalina perattenuata*, M. and H. (?) (rr)

In addition at other localities has been found the following species:

5. *Spirorbis* sp.
   Probably the *S. orbiculostoma* of Swallow.[2]

The light gray limestone of No. 9 contains an abundance of a few species of small Lamellibranchia which constitute a characteristic Permian fauna. An exposure west of Wolf Creek, on Sec. 15 of Four Mile township, Morris county, afforded the following species:

1. *Pleurophorus subcuneatus*, M. and H. (a)
2. *Bakevellia parva*, M. and H. (c)
3. *Yoldia* (?) *subscitula*, M. and H. (rr)
4. *Edmondia Calhouni*, M. and H. (?) (r)
   Small specimens similar to the form figured by Geinitz as belonging to this species (see Fig. 2, Pl. II., Carb. und Dyas, Nebraska).
5. *Nautilus eccentricus*, M. and H. (?) (c)
6. *Aclis Swalloviana*, (Geinitz) Meek. (r)
7. Small *Gastropod* cf. *Orthonema* sp. (rr)
   Specimens showing *Stylolites* structure.

The limestones interstratified with the Florence flint contain

[1] The striæ and characters of these specimens apparently agree with the form noted in some of the early papers as *Orthisina umbraculum*, Schloth, sp. (?) for which Meek and Hayden proposed the specific name *O. multistriata* (Proc. Acad. Nat. Sci. Phil., Vol. XI., p. 26).

[2] Described without figure in Trans. Acad. Sci. St. Louis, Vol. I., p. 181.

a small number of species; the following list having been obtained from the bluffs along the railroad northeast of Florence:

1. *Productus semireticulatus*, (Martin) de Koninck. (c)
2. *Productus costatus*, Sowerby. (rr)
3. *Derbya multistriata*, (M. and H.) Prosser. (r)
4. *Chonetes granulifera*, Owen. (c)
5. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. = *A. argentea*, (Shep.) Keyes. (rr).
6. *Bryozoa*, sp. (rr)
7. *Coral*, sp. (rr)

From other exposures have been obtained the following additional species:

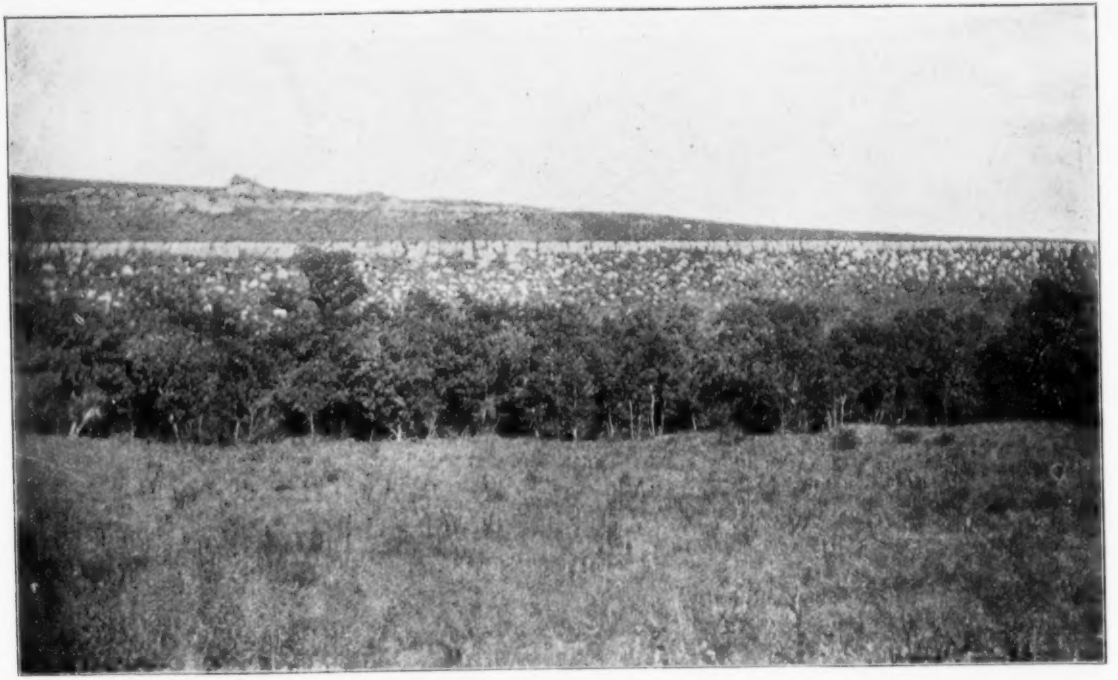
8. *Meekella striato-costata*, (Cox) White and St. John. (c)
9. *Chænomya minnehaha* (Swallow) M. and H. (?) (rr)
10. *Productus nebrascensis*, Owen. (rr)
11. *Sedgwickia* (?) *altirostrata*, Meek and Hayden. (rr)
12. *Phillipsia*, sp. (r)

Probably the most fossiliferous zone of the formation is No. 14, the buff shaly limestones between the Florence flint and the massive limestone. It is essentially a Brachiopod fauna in which there is an abundance of a few large species. In the old quarry one mile northeast of Florence is the following fauna:

1. *Derbya multistriata*, (M. and H.), Prosser. (aa)
   This is probably the species identified by Dr. Newberry, as *Orthisina umbraculum* from the beds of similar age in Morris county.[1]
2. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. (aa)
3. *Productus semireticulatus*, (Martin) de Koninck, var. *Calhounianus*, Swallow. (a)
   Meek considered Swallow's *P. Calhounianus* a synonym of *P. semireticulatus*;[2] but in the Cottonwood and Kansas sections it can usually be distinguished from the *P. semireticulatus*, and it seems distinct enough to be considered a variety.

[1] Rept. Macomb Exp. Exped., p. 21.

[2] Final Rept. Nebraska, Pt. II., p. 161.



No. 3. General appearance of the Fort Riley limestone near the top of the bluff north of Fort Riley, Kansas. Above the Fort Riley limestone are thinner limestones in which fossils are common.

4. *Meekella striato-costata*, (Cox) White and St. John. (a)
5. *Derbya crassa*, (M. and H.) H. and C. (c)
6. *Straparollus* (*Euomphalus*) *subquadratus*, Meek and Worth (c)
7. *Meekella* (?) *Shumardiana*, (Swallow) Williams. (c)
8. *Spirifera* (*Martinia*) *planoconvexa*, Shum. (c)
9. *Aviculopecten occidentalis*, (Shum.) M. and W. (rr)
10. *Straparollus* (*Euomphalus*) *subrugosus*, M. and W. (?) = *S. catilloides*, (Con.) Keyes. (rr)
11. *Pseudomonotis Hawni*, M. and H. (rr)
12. *Schizodus* cf. *Wheeleri*, (Swallow) Meek. (rr)
13. *Allorisma subcuneatum*, M. and H. (rr)
14. *Sedgwickia altirostrata*, M. and H. (rr)
15. *Chænomya minnehaha*, (Swal.) M. and H. (rr)
16. *Polypora submarginata*, Meek. (rr)
17. *Fenestella Shumardi*, Prout (?) (rr)
18. *Chætetes*, sp. (c)
19. Segments of *Crinoid* stems. (r)

From other exposures in the vicinity of Florence, the following additional species were collected:

20. *Myalina kansasensis*, Shum. (rr)
21. *Myalina perattenuata*, M. and H. (rr)
22. *Pinna peracuta*, Shum. (?) (rr)
23. *Septopora biserialis*, (Swallow) Waagen (rr)
24. *Phillipsia sangamonensis*, M. and W. (?) (rr)
25. *Spirorbis* cf. *permianus*, King. (r)
26. *Edmondia*, sp. (rr)
27. *Archæocidaris*, plates and spines. (c)
28. *Chonetes granulifera*, Owen. (rr)
29. *Aviculopecten* cf. *carboniferous*, (Stevens) Meek. (rr)
30. *Straparollus* (*Euomphalus*) cf. *pernodosus*, M. and Worth. (rr)
30. *Bryozoa*, sp. (rr)

In some localities certain layers of the shaly buff limestones —No. 16 of the section—overlying the more massive limestone contain a Lamellibranch fauna composed of a large number of a few Permian species. The best localities noted for this zone are

in the quarries of the shaly limestones on the Kansas River, one mile west of Junction City and north of Fort Riley. Only a limited time was available for collecting at these localities, but the following list was obtained which would be increased by by more careful search:[1]

1. *Bakevellia parva*, M. and H, (a)
2. *Pleurophorus subcuneatus*, M. and H. (c)
3. *Pleurophorus*, sp. (a)
   This is probably the species listed as *Solemya* by Meek and Hayden[2] in their Kansas valley section.
4. *Aviculopecten occidentalis*, (Shum.) Meek and Worth. (c)
5. A small *Gastropod* smooth, internal impressions with seven whorls which taper regularly to the apex. cf. *Loxonema Geinitziana*, King (Mon. Perm. fossils, Pl. XVI., f. 31).
6. (?) *Euomphalus*, sp. (r).

The chocolate and greenish shales—No. 17—overlying the Florence shaly limestones are not fossiliferous; but the yellowish shales contain a few species.

In the Marion flint or limestone—No. 18—is a limited number of fossils which are principally Brachiopods. The following species were obtained in the city of Marion or its vicinity:

1. *Productus semireticulatus*, (Martin) de Koninck, var. *Calhounianus*, Swallow. (r)
2. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. = *A. argentea*, (Shep.) Keyes. (r)
3. *Pinna peracuta*, Shumard. (rr)
4. *Bryozoa*, sp. (rr)
5. *Archæocidaris* spines and plate. (r)

[1] It was in this zone, near Junction City and Fort Riley, that Professor Hay found the *Nautiloidea*, three species of *Metacoceras* and one *Phacoceras* which were described by Professor Hyatt (Geol. Surv., Texas, 2d. An. Rept., 1890, pp. 336, 339, 340, 347) Later, the *Phacoceras Dumbli* was changed to the genus *Stenopoceras* (*Ibid.*, 4th An. Rept., 1893, p. 446). For reference to their stratigraphic position see Professor Hay (Trans. Kans. Acad. Science, Vol. XIII., pp. 37, 38; and Eighth Bien. Rept. State Board Agri., Kansas, Vol. XIII., p. 104, fossils of No. 12 of the Fort Riley section).

[2] Proc. Acad. Nat. Sci., Phil., p. 17, fauna of Bed No. 11.

While in the yellowish shales—No. 19—between the flint and concretionary limestone are:

1. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. = *A. argentea*, (Shep.) Keyes. (c)
2. *Productus semireticulatus*, (Martin) de Koninck. (r)
3. *Derbya multistriata*, (M. and H.) Pros. (?) (rr)
4. *Derbya crassa*, (M. and H.) H. and C. (r)
5. *Septopora biserialis*, (Swallow) Waagen. (r)
6. *Myalina recurvirostris*, M. and W. (rr)
7. *Archæocidaris*, sp. (c)
8. *Aviculopecten*, sp. (rr)
9. (?) *Edmondia*. sp. (rr)
10. *Crinoid* stems.[1]

Finally, in the massive concretionary layers, and in the concretions themselves, are fossils among which Brachiopods are the most numerous and characteristic. The following species were obtained in Marion county:

1. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. = *A. argentea* (Shep.) Keyes. (rr)
2. *Aviculopecten occidentalis*, (Shum.) M. and W. (?) (rr)
3. *Edmondia*, sp. (rr)
4. *Productus semireticulatus*, (Martin) de Koninck. (rr)
5. *Derbya multistriata*, (M. and H.) Prosser. (r)
6. *Septopora biserialis*, (Swallow) Waagen. (r)
7. *Archæocidaris*, *sp.* (c)
8. *Crinoid* segments.

Palæontologically the Marion concretionary limestone is an important stratigraphic horizon for in the higher fossiliferous rocks Brachiopods are seen at rare intervals and rapidly disappear. The fauna of the succeeding rocks consists almost entirely of Lamellibranchia and is composed of species which are

[1] Professor Broadhead stated that at Marion, "*Aviculopecten occidentalis* and *Fusulina cylindrica* were the only fossils seen" (Trans. St. Louis Acad. Science, Vol. IV., Pt. III., p. 492). I have not yet seen *Fusulina* as high as the Marion horizon and Meek and Hayden did not find them above a thin limestone which they reported as thirty-five feet above the horizon of the Cottonwood limestone (Proc. Acad. Nat. Sci. Phil., Vol. XI., p. 17, No. 22), which would locate it in the lower part of the Neosho formation.

quite universally considered as Permian. As previously stated, the Marion flint and concretionary limestone form a horizon which is readily traced in the field, as well as a clearly marked stratigraphic line, so that it is well adapted to serve as the line of separation between two formations. In fact it is the only sharply defined stratigraphic line in this part of the series, and such a classification is further supported by the almost entire disappearance of Brachiopods, although a few specimens continue somewhat higher in accordance with similar facts noted in reference to other formations.

Comparison of the Chase formation with Swallow's section.— It is perfectly clear from a comparison of the sections that the horizon termed the *Strong flint* in the Chase formation comprises beds No 62–58 inclusive of Swallow, to which he gave a thickness varying from thirty-six to sixty-three feet, and which is called forty-two feet in the Chase formation. The flint stratum at the base of the Chase formation, No. 1 of the section, equals No. 62 of Swallow's list which he called the "fifth *cherty limestone*" and described as "a light drab and buff cherty magnesian limestone,[1] twelve feet" containing "*Productus Calhounianus, Chonetes mucronata, Orthisina* like *umbraculum, Athyris* like *subtilita* and *Crinoids*," near Fort Riley.[2] Swallow called his bed No. 58 the "fourth *cherty limestone*" which corresponds to No 4 of the Strong flint, and he assigned it a thickness varying from ten to twenty-four feet.

The *Florence flint* represents bed No. 54 of Swallow, the "third *cherty limestone*" which he described as "light buff and magnesian, forty feet" containing "*Productus Calhounianus, Orthi-*

[1] The following analysis by Mr. Warren Finney shows that it is not a magnesian limestone.

SiO_2	03.01	per cent.
Al_2O_3	11.73	"
$CaCO_3$	86.35	"
$MgCO_3$	trace	"
Fe_2O_5	trace	"
	101.09	"
CO	38.32	"

[2] Prel. Rep. Geol. Surv., Kansas, p. 14.

sina Shumardiana, *Spirifer* like *lineatus*, *Orthisina* like *umbraculum*" exposed "near Fort Riley, Cottonwood and Fancy Creek."[1]

Swallow estimated the thickness of the beds between the fourth and third cherty limestones, which correspond to the beds between the top of the Strong and the base of the Florence flint, as ranging from forty-nine to sixty-eight feet which in our section is called seventy feet. Again, Swallow estimated the thickness of the beds ranging from the base of the fifth to the third cherty limestone, which represent the beds between the base of the Strong and Florence flints, as varying in thickness from 85 to 131 feet, while in the Chase formation they are assigned a thickness of 112 feet. Swallow reported six feet of shales above the Florence flint and then a massive limestone which he described as "a buff porous magnesian rock[2] in thick beds," containing "*Productus Calhounianus*, *Orthisina Shumardiana*, *Archæocidaris*, *Bakevellia*, etc., eight to ten feet . . . . near Fort Riley, Cottonwood and Fancy Creek" for which he proposed the name "*Fort Riley limestone*." On account of the excellent exposures near Junction City and Fort Riley, Swallow's name, "*Fort Riley limestone*," is an appropriate one for the Kansas Valley region, while in the Cottonwood Valley it is represented by the Florence limestone.[3]

After comparing numerous sections, it does not appear that the massive ledge of limestone exposed in the various ravines and bluffs of this region always represents the same bed; in fact we also find that the higher shaly limestones appear in cer-

[1] Prel. Rep. Geol. Surv., Kansas, p. 14. The "Fancy Creek" mentioned frequently by Professor Swallow is supposed to be the one north of the Kansas River in the northern part of Riley county.

[2] This limestone contains a small percentage of magnesia as is shown by Mr. Finney's analysis:

SiO_2	10.01	per cent.
Al_2O_3	3.74	"
$CaCO_3$	83.53	"
$MgCO_3$	2.17	"
Fe_2O_5	trace	"
	99.45	"
CO_2	36.66	"

[3] For the first statement of this correlation see PROSSER; Bull. Geol. Soc., Amer., Vol. VI., p. 49 f. n.

tain localities as the conspicuous massive ledge. It is important to bear the above statement in mind in stratigraphic work in regard to this horizon, for a greater uniformity of appearance in outcrop has been assigned to this limestone than actually exists.

Above the Fort Riley limestone Swallow also reported variously colored shales and marls sixty-four and a half feet in thickness before reaching the base of the "second *cherty limestone*"—bed No. 44—which he described as "hard, bluish drab and very cherty, four feet. *Productus*, *Myalina* and *Spirifer*" exposed on the "Cottonwood and Carey Creek."[1] This bed is probably the *Marion flint* of the Chase formation which answers quite well to the above description. The base of the Florence flint is a clearly marked stratigraphic line, and Swallow assigned a thickness of from 118½ to 120½ feet to the beds between the bases of his third and second cherty limestones, while in the Chase formation, from the base of the Florence flint to that of the Marion, it is given as 126 feet. From sixteen to twenty-four feet above the top of the second cherty limestone is bed No. 40 of Swallow which he called the "first *cherty limestone*" and characterized it as "a brownish-buff magnesian limestone with cherty concretions, four feet. *Productus Calhounianus*, *semireticulatus* (?), *Athyris subtilita?*, *Archæocidaris*," exposed on "Cottonwood and Carey Creek."

It is inferred that this "first cherty limestone" of Swallow is the *Marion concretionary limestone* of the Chase formation, and it will be noticed that Swallow mentions "cherty concretions" instead of simply "chert" as in his description of the other cherty limestones, although he does not refer to the prominent stratigraphic feature of this bed.

Finally, Swallow gave the total thickness of the beds from the base of his fifth cherty limestone—No. 62—to the top of the first cherty limestone—No. 40—as ranging from 223½ to 279½ feet.[2] These beds include all the cherty limestones of

[1] Prel. Rep. Geol. Surv., Kansas, p. 13. The Carey Creek frequently mentioned by Swallow is supposed to be the creek of that name in the eastern part of Dickinson county.

[2] In the section there are a few beds to which no thickness was assigned by Swallow, but it is supposed those were regarded as local and simply a modification of the other beds so that their thickness was considered in those beds.

Swallow and represent those which we have described as the Chase formation, with a thickness of 265 feet. The Chase formation is confined to what Swallow called the Lower Permian, and he drew the line separating the Lower from the Upper Permian at the top of bed No. 31 which he gave as from 49 feet 1 inch to 82 feet 3 inches higher than the bed which we regard as representing the top of the Chase formation.

Comparison with Meek and Hayden.—The Strong flint corresponds to bed No. 18 of Meek and Hayden, which they described as a "light gray and whitish magnesian limestone containing *Spirigera, Orthisina umbraculum* (?), *O. Shumardiana, Productus Calhounianus, Acanthocladia americana* and undetermined sp. *Cyathocrinus;* lower part containing many concretions of flint. Fort Riley and on Cottonwood Creek, whole thickness about 40 feet;"[1] while in the Chase formation we have called it 42 feet. Again, the Florence flint is bed No. 14 of Meek and Hayden, which they give as 38 feet thick, while the Florence or Fort Riley massive limestone is No. 12, which they state "forms distinct horizon near summit of hills in vicinity of Fort Riley, also seen on Cottonwood Creek—7 to 8 feet." Number 11 of Meek and Hayden represents the shaly limestones above the massive Florence limestones (No. 16 of the Chase section) which they describe as a "light grayish and yellow magnesian limestone in layers and beds, sometimes alternating with bluish and other colored clays, and containing *Solenomya*, a *Myalina* near *squamosa*, *Pleurophorus* (?) *subcuneata*, *Bakevellia parva*, *Pecten*, undt., and a *Euomphalus* near *E. rugosus;* also a *Spirigera* allied to *S. subtilita* but more gibbous, *Orthisina umbraculum* (?), *O. Shumardiana*, etc. Locality, summit of the hills near Fort Riley and above there; also seen on Cottonwood Creek—25 to 35 feet." Meek and Hayden gave the thickness of the beds from the base of the lower flint—No. 18—to the top of these buff, shaly limestones—No. 11—as ranging from 182 to 193 feet; while in our section of the Chase formation the thickness of the same beds is given as 176 feet. Meek and Hayden considered that the base of the Permian could

[1] Proc. Acad. Sci. Phil., Vol. XI., p. 17.

not be lower than the top of No. 11, although it might be still higher and include No. 10.[1]

Meek and Hayden apparently failed to notice the Marion flint and concretionary limestone, which probably forms a part of their No. 10, so it is not possible to compare closely their section with the upper part of the Chase formation.

Comparison with Hay's Fort Riley section.—Professor Hay has described a section near Fort Riley[2] which probably includes all of the rocks referred to the Chase formation. The Strong flint is No. 5 of Hay's section, which he termed "the lower flint beds" or the "Wreford limestone," 25 feet thick.[3]

The Florence flint is No. 9 of Hay, which he called "the upper flint beds," from 25 to 30 feet in thickness; and 15 feet higher in his massive "Fort Riley main ledge"—No. 11—6 feet thick, capped by shaly limestones from 30 to 40 feet in thickness. Then come 50 to 60 feet of shales, and at the top of the section is No. 14 which is described as composed of "impure limestones with some flints and numerous geodes," 10 feet in thickness. It is probable that this highest bed represents the Marion flint or concretionary limestone, which apparently occurs in the bluff above the railroad cut west of Chapman. According to Professor Hay, the thickness of the rocks from the base of the Wreford

[1] Proc. Acad. Sci. Phil., Vol. XI., pp. 20, 21, where it is stated that, "If we do not admit the existence in this region of an intermediate group of rocks, connecting by slight gradations the Permian above with the Coal Measures below, and must draw a line somewhere, below which all is to be regarded as Carboniferous, and all above as Permian, we should certainly, upon palæontological principles alone, carry this line up as far as the top of division No. 11. . . . . Indeed the fact that some of the Permian types occurring in No. 10 were first introduced in beds below this, containing many Carboniferous species would seem to indicate that even No. 10 may possibly have been deposited just before the close of a period of transition from the conditions of the Carboniferous to those of the Permian epoch."

About the same time Meek and Hayden stated in the American Journal of Science —"We think only the Upper Permian of their section [Swallow and Hawn] really represents the Permian rocks as developed on the other side of the Atlantic" (Second series, Vol. XXVII., Jan. 1859, p. 35); while the Lower Permian of Swallow they called Permo-Carboniferous.

[2] Eighth Bien. Rept. State Board Agri. Kansas, p. 104.

[3] This horizon as exposed in the Kansas River Valley was discussed by Prosser in the Bull. Geol. Soc. Am., Vol VI., pp. 47, 48.

limestone to the top of the impure limestone at the summit of the section — No. 14 — varies from 213 to 238 feet. However, the Professor underestimated the thickness of the rocks from the base of the Wreford limestone to the base of the upper flint at Fort Riley by about 27 feet,[1] and if this be added to the 238 feet it will give a thickness of 265 feet, which is exactly the thickness which we have assigned to the Chase formation.

THE MARION FORMATION.

Succeeding the Chase formation are thin, buff limestones and shales; higher, marls and shales with gypsum; and lastly, colored shales and marls which continue to the base of the brown Dakota sandstones of the Cretaceous. These rocks cover the greater part of Marion county and are exposed in many places so it is proposed to call them the *Marion formation.* The natural opportunities are not as favorable for constructing an accurate section here as in the Chase formation, on account of the comparatively level character of the region, presenting few steep bluffs and strata that may be readily traced across the country. The rocks composing the formation are estimated to have a thickness of 400 feet.

Some 50 to 60 feet above the Marion and concretionary limestone is a buff limestone which contains large numbers of small Lamellibranchia and twenty feet higher is a buff limestone containing large Lamellibranchia. In some localities near this horizon is a limestone containing *Pleurophorus* in which are large concretions; these are well shown on sections 34 and 27, north of Wonsevu. On Turkey Creek, south of the Smoky Hill Valley and Abilene, is a conglomerate rock from 15 to 20 feet thick, which is some 150 feet above the base of the formation. On the south bank of the river opposite Abilene is a buff limestone containing Lamellibranchia, which is probably a little below the conglomerate.

Palæontology.—In the Marion formation but few Brachiopods

[1] Professor Hay gave 77 feet as the thickness of the rocks from the base of the lower flint (Wreford limestone) to the base of the upper flint beds; while I found the thickness of the same rocks to be near 104 feet on the hill at Fort Riley.

have been found, and the most abundant and characteristic fossils are the small Lamellibranchia which are not uncommon in the lower part, but gradually become rare in the upper portion until fossil forms almost entirely disappear.

In the grayish limestones in the lower part of the formation the following species, from numerous localities in Marion and Morris counties, have been obtained:

1. *Pleurophorus subcuneatus*, M. and H. (aa)
2. *Bakevellia parva*, M. and H. (c)
3. *Yoldia subscitula*, M. and H. (rr)
4. *Macrochilina* cf. *angulifera*, White. (rr)
5. *Pleurophorus subcostatus*, M. and W. (?) (rr)
6. *Nautilus eccentricus*, M. and H. (?) (rr)
7. *Schizodus curtus*, M. and W. (r)
8. *Schizodus ovatus*, M. and H. (r)
9. *Dentalium Meekianum*, Geinitz. (?) (rr)

A little higher are buff limestones which contain large Lamellibranchia as follows:

1. *Aviculopecten occidentalis*, (Shum.) Meek. (aa)
2. *Myalina permiana*, (Swallow) M. and H. (a)
3. *Pseudomonitis Hawni* (M. and H.) (a)
4. *Pseudomonitis Hawni* (M. and H.) var. *ovata*, M. and H. (r)

In Township 22 S., Range 6 E., Sec. 18, west of Wonsevu, a limestone near the top of the hill west of Cedar Creek, contains the fauna given below:

1. *Pseudomonotis Hawni* (M. and H.) var. *ovata*, M. and H. (r)
2. *Pseudomonotis Hawni* (M. and H.) (c)
3. *Pseudomonotis* cf. *variabilis*, Swallow. (r)
4. *Pleurophorus subcuneatus*, M. and H. (c)
5. *Nautilus eccentricus*, M. and H. (?) (r)
6. *Aviculopecten occidentalis*, (Shum.) M. and W. (rr)
7. *Yoldia subscitula*, M. and H. (rr)
8. *Nuculana bellistriata*, Stevens, var. *attenuata*, Meek. (rr)
9. *Derbya multistriata*, (M. and H.) Pros. (?) (c)
10. *Septopora biserialis*, (Swal.) Waagen. (?) (rr)

From the buff limestones and shales on the south bank of

the Smoky Hill River, south of Abilene, and not far below the Abilene conglomerate, the following species were collected:

1. *Pleurophorus subcuneatus*, M. and H. (a)
2. *Bakevellia parva*, M. and H. (c)
3. *Edmondia Calhouni*, M. and H. (?) (c) As identified by Geinitz (see Pl. II., Fig. 2 of Carb. und Dyas Nebraska).
4. *Yoldia subscitula*, M. and H. (rr)
5. *Schizodus curtus*, M. and W. (?) (rr)
6. *Nucula* cf. *Beyrichi*, v. Schauroth; also cf. *N. parva*, McChesney. (a)
7. *Aviculopecten* (?) sp. (rr) } very imperfectly preserved.
8. *Septopora* (?) sp. (rr) }
9. Small *Gastropod* cf. *Aclis Swalloviana*, (Geinitz) Meek. (r)

Above this horizon the fossils are less frequent and in the upper part of the formation seem to completely disappear.

Comparison of the Marion formation with Swallow's section.— The Marion formation commences with bed No. 39 of Swallow, but I have not been able to clearly identify the different beds of his section with the various strata of this formation as in the Chase, Neosho, and Cottonwood formations. Swallow described bed No. 23 as "bluish-drab shale, with calcareous concretions," below which are limestones "full of Permian *Acephala* and *Cephalopods*,"[1] and gave this bed as from 49 feet 1 inch to 103 feet 9 inches above the top of his first cherty limestone, which I have considered as the representative of the Marion concretionary limestone. The thickness of the rocks between the concretionary layer of bed No. 23 and the base of the formation indicate that it may be the upper concretionary layer which I have described northeast of Wonsevu. From 16 to 48 feet higher is the base of a "calcareous conglomerate" 1 to 24 feet thick—bed No. 17—and above this is a "concretionary limestone," 2 to 15 feet in thickness, which are stated to occur in "Fancy and Turkey Creeks and Cottonwood."[2] The maximum thickness of the rocks from the base of the calcareous conglom-

[1] Prel. Rept. Geol. Surv. Kans., p. 12.

[2] Ibid., p. 11.

erate to the base of our Marion formation, according to Swallow, is 151 feet 7 inches, which indicates that the conglomerate we noted in Turkey Creek, south of Abilene, and estimated as 150 feet above the base of the Marion formation is the "calcareous conglomerate" of Swallow. From 61 to 124 feet higher is the top of Swallow's Permian; but Professor Mudge stated that all of Swallow's Triassic system, except the two upper beds—Nos. 3 and 2—should be referred to the Permian.[1] Calling bed No. 4 of Swallow the top of the Permian, the beds of his section corresponding to those of the Marion formation have a thickness ranging from 334 feet 11 inches to 544 feet 7 inches.

Comparison with Meek and Hayden.—The conglomerate noted on Turkey Creek south of Abilene is apparently bed No. 9 of Meek and Hayden which they described as a "rough conglomerated mass, composed of fragments of magnesian limestone and sandstone, with sometimes a few quartz pebbles, cemented by calcareous and arenaceous matter . . . . south side Smoky Hill River, ten or twelve miles below Solomon's Fork, 18 feet."[2]

From the base of this conglomerate limestone to the apparent base of the Dakota sandstone of their section—bed No. 2—is 388 feet. If their concretionary limestone—bed No. 9—which, according to the description and locality agrees with the one seen south of Abilene, be 150 feet above the base of the Marion formation, then making this correction in their estimate of thickness would give 538 feet as the thickness of the Marion formation.

CONCLUSION.

The length of this paper precludes any complete discussion of the geologic position of these formations and their correlation with deposits of similar age in different parts of the world, therefore such a review must be deferred until the detailed geo-

[1] First Bien. Rept. State Board Agri. Kansas, 1878, p. 66 and f. n., where the Professor said, "the other numbers [aside from 2 and 3] of his Triassic belong to the Permo-Carboniferous." Professor Mudge did not attempt to separate the Permian and Upper Carboniferous, for he said, "These two groups may be described together, as there is no line of division, either by physical deposits or fossils" (*ibid.*, p. 70).

[2] Proc. Acad. Nat. Sci., Philadelphia, Vol. XI., p. 16.

logic report of the region is published. In order to appreciate the questions involved in the correlation of these formations, it is important to mention briefly the proposed classifications which have appeared within the last few years.

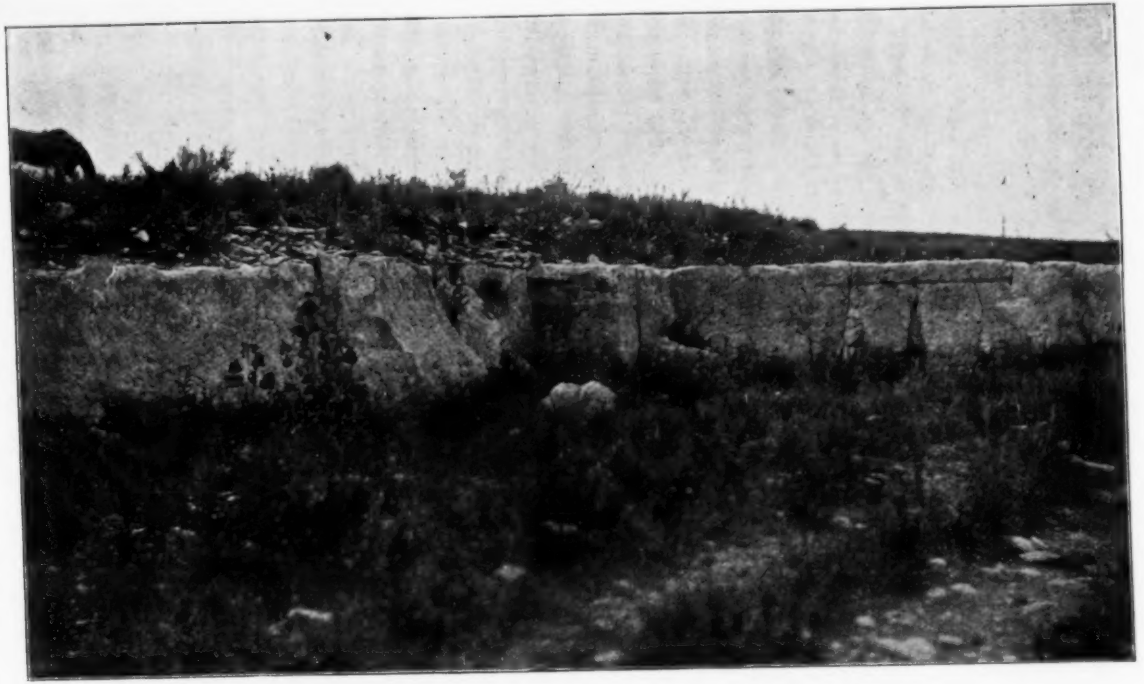
After the publication of the final views of Meek and Hayden in 1872, which referred especially to the Upper Palæozoic of southeastern Nebraska,[1] the next important announcement was that of Dr. Newberry at the Berlin International Geological Congress in 1885, where he is reported to have stated that "He had traversed all the States and Territories of the Union, and had examined the so-called Permian in many localities, but, in his judgment, it could not be separated from the Coal Measures.

It is true that in the upper Carboniferous strata certain genera of mollusks appear, which are regarded as characteristic of the Permian, such as *Monotis*, *Bakevellia*, *Pleurophorus*, etc., but these are associated with and outnumbered by the most characteristic Coal-measure forms, such as *Spirifer cameratus*, *Athyris subtilita*, *Productus semireticulatus*, etc., and were by these inseparably bound to the Carboniferous system."[2] As far as the palæontology is concerned we have shown above that the statement of Dr. Newberry is entirely incorrect in regard to the range of the Brachiopods in Kansas. We have not seen *Spirifer cameratus* above the top of the Wabaunsee formation, or the last two species above the Chase formation. However, the most misleading part of the statement is that these Brachiopods outnumber the Lamellibranchia in all of these deposits. In the Neosho and Chase formations possibly the Brachiopods are the more abundant; but in the Marion formation they are extremely rare, a few specimens of *Derbya* only having been found, and the Permian Lamellibranchia are conspicuously the dominant fossils.

In 1889, Dr. Th. Tschernyschew, the able Director of the

[1] Final Rept. U. S. Geol. Surv. Nebraska and portions of adjacent Territories. The field work upon which this report was based, was accomplished during 1867, and the report was submitted for publication on March 1, 1868, but was delayed until 1872 (see pp. 3, 139).

[2] The Work of the International Congress of Geologists, 1886, p. 29. Dr. Newberry's statement of the absence of the Permian in America was published in the Am. Jour. Sci., 3d series, Vol. XXX., December, 1885, p. 469.



No. 4. Near view of the Fort Riley limestone North of Fort Riley, Kansas.

Russian Geological Survey, stated that he agreed with Waagen in considering the Nebraska City beds, in southeastern Nebraska, similar in age to the Artinsk sandstone group of the Ural Mountains, which he called Permo-Carboniferous.[1]

In 1891 appeared Waagen's exhaustive work on the geological classification of the Upper Palæozoic rocks of the Salt-Range in northern India,[2] in which the author shows the striking relations "that undoubtedly exist between the American Coal Measures and the deposits of the Salt-Range."[3] Waagen followed Neumayr and made two large divisions of the Palæozoic; for the upper division, which included the Carboniferous and Permian systems, he proposed the name, "Anthracolithic epoch" which he defined as equivalent to Neumayr's "Upper Palæozoics."[4]

Waagen prepared a table giving his views of the correlation of the Upper Palæozoic strata of the Salt-Range with similar deposits of other countries,[5] and the Permian system was composed of the Permo-Carboniferous, Rothliegendes, and Magnesian Limestone groups. The correlation of the American deposits are of special interest to us, and represents that part of the table to which we shall refer. Waagen, for North America, drew the dividing line between the Carboniferous and Permian systems at the top of the "Upper Productive Coal Measures" and referred the "marine beds of Plattsmouth [Nebraska] and beds below (up to about 2000 feet in thickness) down to the

[1] Mém. Com. Géologique, Vol. III., No. 4, p. 366. In Murchison's description of he geology of Russia, the Artinsk sandstones were referred to the Carboniferous (Geol. Russia in Europe and the Ural Mts., Vol. I., 1845, p. 129). The correlation and palæontology of the Nebraska City beds have been carefully discussed by Professors Marcou, H. B. Geinitz and Meek, and the consideration of this question is reserved for a later paper. Professor Hicks at a later date briefly described deposits in Gage county, in the southern part of Nebraska, which probably belong to the Permo-Carboniferous or Permian of Kansas (Am. Naturalist, Vol. XX., 1886, pp. 881–3; abstract in Proc. Am. Asso. Adv. Science, Vol. 35, 1887, pp. 216, 217).

[2] Mem. Geol. Surv. India, Palæ. India. Ser. XIII., Salt-Range Fossils, Vol. IV., Pt. II., Geological Results, Calcutta.

[3] Ibid., p. 201.

[4] Ibid., p. 241.

[5] Ibid., "Tabular view showing the relations of the Salt-Range Upper Palæozoic strata to the deposits of other countries," op. cit., p. 238.

Productive Coal Measures," to the Permo-Carboniferous group. The upper part of the group was correlated with the Artinsk stage of Russia.

This group would include at least the Wabaunsee formation of Kansas which contains a fauna practically identical with that of the Upper Coal Measures, and as far as the deposits of Kansas are concerned there seems to be no reason for considering the formation as of Permian or Permo-Carboniferous age. The "red and gray sandstones and shales of Nebraska City" are correlated with the Rothliegendes by Waagen, who clearly regards them as younger than the Artinsk stage. Then the "red sandstones and shales of Texas" containing Vertebrates and Cephalopods, which have been described by Cope and White,[1] are referred to the lower part of the Magnesian limestone which forms the upper group of Waagen's Permian system. Finally, the "limestones and shales, with *Pseudomonotis hawni* (—*speluncaria*) of Kansas, red gypsum beds of Texas" are regarded as equivalent to the remaining portion of the Magnesian limestone group and consequently represent the upper part of the Permian system.

It may be said in general in reference to Waagen's correlations that so far as the North American deposits are concerned he carried the Permo-Carboniferous group too low. If it be considered better to put all the beds in either the Carboniferous or Permian system, it might be just as well to refer the deposits generally called Permo-Carboniferous to the Permian.[2] If such correlation be agreed upon then in Kansas, the line separating the Cottonwood and Neosho formations would become the line of division between the Carboniferous and Permian systems. In the Cottonwood formation is the massive *Fusulina* limestone[3]

[1] EDWARD D. Cope: Trans. Am. Phil. Soc., 1888, Vol. XVI., pp. 285–288.

CHARLES A. WHITE: The Texan Permian and its Mesozoic types of fossils. Bull. U. S. Geol. Surv., No. 77, 1891, pp. 39, Pl. IV.

[2] In this connection see a paper by Professor James P. Smith on "The Arkansas Coal Measures in their relations to the Pacific Carboniferous province" (The JOURNAL OF GEOLOGY, Vol. II., 1894, pp. 187–205). On the "Correlation Table" at the close of the paper (p. 204) the "Permo-Carboniferous of Kansas and Nebraska" is referred to the Permian.

[3] The *Fusulina* limestones of Europe and Asia belong either in the Upper Carboniferous or lower Permian, hence, the massive Cottonwood limestone with its millions of

with the fossiliferous shales above, which is an excellent formation to be traced in the field, and so would furnish a well-marked line for separating the two systems in areal geology.

In 1890, Professor W. F. Cummins divided the Texan Permian[1] into three formations or beds, as he called them, and named them in ascending order the Wichita, Clear Fork, and Double Mountain beds.[2] In the succeeding report the upper formations of the Coal Measures were named the Albany, Cisco, and Canyon,[3] the Albany being the higher and just below the Permian according to Professor Cummins' classification. The report also contains plates showing the classification of the Carboniferous and Permian,[4] and lists of fossils from the Coal Measures.[5] The Permian is more fully described than in the preceding reports and is accompanied by sections and references to the palæontology[6] as elaborated by Dr. White.[7] The fossil plants collected in the upper part of the Wichita formation were identified by Professor I. C. White and Fontaine as essentially the same as the flora described by them from the beds above the Waynesburg Coal in West Virginia which they had referred to the Permian.[8] In 1893 Professor Cummins again discussed the Permian formations of Texas, reviewed the history of the discovery of Permian rocks in this country, and the question of their correlation with the Permian of Europe and Asia.[9] In this report

Fusulinas, which is near the close of their range in Kansas, may be considered as near the line of division between these two systems. See Dr. E. Kayser's Text Book of Comparative Geology, English ed., 1893, pp. 127, 144, 162. On p. 147 Kayser says "west of the Mississippi . . . . the Upper Carboniferous is represented by limestones rich in *Fusulina* with an abundant marine fauna."

[1] For an earlier summary of the papers describing the Permian of Texas, see Professor R. T. Hill; Bull. U. S. Geol. Surv., No. 45, 1887, pp. 62–69.

[2] Geol. Surv. Texas, First An. Rept., pp. 186–189; and LXIX., LXX.

[3] Second An. Rept. Geol. Surv. Texas, 1891, pp. 372–375.

[4] *Ibid.*, pp. 361, 373.

[5] *Ibid.*, Particularly pp. 393, 394.

[6] *Ibid.*, pp. 394–424.

[7] Bull. U. S. Geol. Surv., No. 77.

[8] Bull. Geol. Soc. Amer., Vol. III., 1892, pp. 217, 218.

[9] Geol. Surv. Texas, Fourth An. Report., pp. 212–232.

it is stated: "It is still too early to attempt exact correlation, but it is quite probable that the Albany division of my Coal Measures will prove to be the same as the beds at Fort Riley, Kansas."[1] Professor Cummins further said that the *Phacoceras Dumbli*, Hyatt which is found at Fort Riley, Kansas, came from "the very top of the Albany division in Texas . . . . and as the form is supposed to have but a short range in time it would go far to assist in correlating the strata."[2] If Professor Cummins be correct in the above correlation, then it is probable that the Albany formation ought to be correlated with the Permo-Carboniferous of Kansas.[3]

In reviewing these reports Professor Marcou correlated the Albany division with the Nebraska City deposits of Nebraska, and the Cisco division he considered as related to the Plattsmouth group of Nebraska.[4] While Professor Smith draws the line between the Coal Measures and the Permo-Carboniferous through the upper part of the Cisco formation, including in the Permo-Carboniferous the "uppermost Cisco beds of Texas, with *Ammonites* (*Popanoceras*) *Parkeri*, Heilprin," which he correlates with the Artinsk stage.[5]

After reviewing all the published opinions regarding the correlations of the Upper Palæozoic of the United States and after a consideration of the fauna and the lithological and stratigraphical characters of these formations as exposed in Kansas, it seems well to classify them as indicated on the chart on p. 797. Consequently we would refer the Wabaunsee and Cottonwood formations to the Upper Coal Measures. The Neosho and Chase formations are transitional from the Upper Coal Measures to the Permian, as first defined by Murchison for Russia, and belong to the division which has generally been called Permo-Carboniferous, in this country. In accordance with the views of the majority of

[1] Ibid., p. 222.

[2] Ibid., p. 223.

[3] Professor Cummins is not sure but that "the Wichita and Albany divisions are but different facies of the same formation" (ibid., p. 223).

[4] Am. Geol. Vol. X., 1892, p. 369; see "Table of Classification" on pp. 376, 377.

[5] JOURNAL GEOLOGY, Vol. II., 1894, p. 194; see "Correlation Table" on p. 204.

present European geologists familiar with this problem it is probably better to include the Permo-Carboniferous rocks of Kansas in the Permian series.[1] We see no decided objection to such a classification, while the appearance and the prominence of the *Pseudomonotis* fauna in the Neosho formation furnishes a strong reason on the biologic side for such correlation. The Marion formation belongs to the undoubted Permian and contains only fossils which are characteristic of that series.

CHARLES S. PROSSER.

UNION COLLEGE,
Schenectady, N. Y., July, 1895.

[1] The classification of the Permian as a subdivision of the Carboniferous period or system is in accordance with the usage of the U. S. Geological Survey (See Tenth An. Rept. U. S. Geol. Surv., p. 66).

TABLE SHOWING THE STRATIGRAPHIC POSITION AND CHARACTER OF THE FORMATIONS COMPRISING THE UPPER PALÆOZOIC OF CENTRAL KANSAS.

Period	Series	Formation or Stage	Stratigraphic Characters of the Different Beds	Characteristic Fossils	Thickness of Beds	Total Thickness	Thickness of Formation
Cretaceous		*Dakota*[1] (Meek and Hayden)	Massive dark brown or red sandstones.	Fossil plants.			
Carboniferous.	Permian.	*Marion* (Prosser)	Variously colored shales and marls. Colored shales and marls alternating with beds of gypsum. Buff limestones and marls.		250±	1390	400±
			Abilene conglomerate.		20±	1140	
			Shaly buff limestones with *Pleurophorus.*	*Pleurophorus subcuneatus, Bakevellia parva, Edmondia Calhouni, Nucula sp.*			
			Buff limestones which contain large *Lamellibranchia.*	*Aviculopecten occidentalis, Myalina permiana, Pseudomonotis Hawni.*			
			Grayish (?) limestones containing plenty of *Bakevellias*, near this horizon in some localities a concretionary limestone. Thin buff limestones with a few *Derbyas.*	..... *Pleurophorus subcuneatus, Bakevellia parva, Schizodus curtus, Schizodus ovatus, Nautilus eccentricus, Yoldia subscitula.*	130	1120	
		Chase (Prosser)	*Marion concretionary limestone;* containing large brown concretions.	*Athyris subtilita, Productus semireticulatus, Derbya multistriata.*	10	990	
			Yellowish shales, few *Brachiopods.*	*Athyris subtilita, Productus semireticulatus, Derbya crassa, Septopora biserialis.*	13+	980	
			Marion flint; light gray limestone generally containing flint.	*Productus semireticulatus, var. Calhounianus, Athyris subtilita Archæocidaris sp.*	4	967	

[1] Perhaps the base of the Dakota should be referred to the Mentor beds of Professor Cragin. (See Am. Geol., Vol. XVI., Sept. 1895, pp. 162, 163.)

TABLE SHOWING THE STRATIGRAPHIC POSITION AND CHARACTER OF THE FORMATIONS COMPRISING THE UPPER PALÆOZOIC OF CENTRAL KANSAS.—*Continued.*

Period	Series	Formation or Stage	Stratigraphic Characters of the Different Beds	Characteristic Fossils	Thickness of Beds	Total Thickness	Thickness of Formation
Carboniferous.	Permian.	*Chase* (Prosser)	Variously colored shales with thin layers of limestone.		62±	963	265
			Buff shaly limestones with *Lamellibranch* fauna.	*Bakevellia parva*, *Pleurophorus subcuneatus*, *Aviculopecten occidentalis.*	22	901	
			Ft. Riley or *Florence limestone;* a massive buff limestone.		5+	879	
			Buff shaly limestones containing an abundant *Brachiopod* fauna.	*Derbya multistriata*, *Athyris subtilita*, *Productus semireticulatus* var. *Calhounianus*, *Meekella striato-costata*, *Straparollus subquadratus*, *Derbya crassa*, *Meekella* (?) *Shumardiana*, *Spirifera planoconvexa*, *Chaetetes sp.*	15	874	
			Florence flint; a massive limestone with prominent layers of flint.	*Productus semireticulatus*, *Chonetes granulifera*, *Derbya multistriata.*	22	859	
			Yellowish, chocolate and greenish shales.		31	837	
			Light gray limestone with a fauna of small *Lamellibranchia.*	*Pleurophorus subcuneatus*, *Bakevellia parva*, *Edmondia Calhouni* (?)	2±	806	
			Shales.		12±	804	
			Shaly buff limestone containing large *Brachiopods.*	*Derbya multistriata*, *Aviculopecten occidentalis.*	10±	792	
			Shales.		15±	782	

TABLE SHOWING THE STRATIGRAPHIC POSITION AND CHARACTER OF THE FORMATIONS COMPRISING THE UPPER PALÆOZOIC OF CENTRAL KANSAS.—*Continued.*

Period	Series	Formation or Stage	Stratigraphic Characters of the Different Beds	Characteristic Fossils	Thickness of Beds	Total Thickness	Thickness of Formation
Carboniferous.	Permian.	*Chase* (Prosser)	*Strong flint;* two strata of light gray limestone containing an abundance of flint in layers, separated by a massive whitish limestone.	*Enteletes hemiplicatus, Athyris subtilita, Chonetes granulifera, Meekella striato-costata.*	42	767	
		Neosho (Prosser)	Yellowish shales with *Brachiopod* fauna.	*Chonetes granulifera, Derbya crassa, Athyris subtilita.*	23	725	130
			Massive gray limestone with *Pleurophorus.*		3+	702	
			Yellowish shales with thin shaly limestones.		36	699	
			Limestone with *Pseudomonotis* at top and bottom, with shales between.	*Pseudomonotis Hawni.*	12	663	
			Green and chocolate colored shales.		20	651	
			Light gray shaly limestones containing *Pseudomonotis.*	*Productus nebrascensis, Pseudomonotis Hawni, Aviculopecten occidentalis, Pleurophorus subcostatus.*	4	631	
			Shales.		4	627	
			Dark gray silicious limestone, weathers to very rough surface.		2+	623	
			Yellowish shales with *Brachiopods.*	*Chonetes granulifera, Productus semireticulatus, Rhombopora lepidodendroides.*	6	621	
			Yellowish, blocky shales containing a *Lamellibranch* fauna.	*Pseudomonotis Hawni, Aviculopecten occidentalis, Meekella striato-costata.*	5	615	

TABLE SHOWING THE STRATIGRAPHIC POSITION AND CHARACTER OF THE FORMATIONS COMPRISING THE UPPER PALÆOZOIC OF CENTRAL KANSAS.—*Continued.*

Period	Series	Formation or Stage	Stratigraphic Characters of the Different Beds	Characteristic Fossils	Thickness of Beds	Total Thickness	Thickness of Formation
Carboniferous.	Permian.	*Neosho* (Prosser)	Greenish and chocolate shales.		11	610	
(?)			Shaly limestones.		4	599	
	Upper Coal Measures.	*Cottonwood* (Prosser)	*Cottonwood shales;* yellowish shales, in the upper part unfossiliferous but containing nodules of gypsum (?); the lower part very fossiliferous.	*Chonetes granulifera, Derbya crassa, Athyris subtilita, Productus semireticulatus, Meekella striato-costata.*	14	595	20
			Cottonwood limestone; light gray massive limestone containing in the upper part immense numbers of *Fusulina.*	*Fusulina cylindrica.*	6	581	
		Wabaunsee (Prosser)	Shales.		40	575	575±
			"*Dry bone limestone;*" a drab to bluish silicious limestone which on weathering forms a rough surface.		10±	535	
			Shales and marls interstratified with limestones. Some of the limestones form thick, massive strata. In the lower part an occasional thin stratum of coal.	*Chonetes granulifera, Productus splendens, P. cora, P. nebrascensis, Spirifer planoconvexus, Athyris subtilita, Hustedia mormonii, Spirifer cameratus, Pinna peracuta, Derbya crassa, Meekella striato-costata, Spiriferina kentuckensis.*	525±	525	
		Missouri (Keyes)					

THE VOLCANICS OF THE MICHIGAMME DISTRICT, OF MICHIGAN (PRELIMINARY).

THIS name is given to a series of volcanic rocks occurring on the Upper Peninsula of Michigan, between Townships 42 and 47 N., and Ranges 30 and 34 W. They are included between the Paint (Mequacumecum) and Michigamme Rivers, and are intersected by their tributaries, the Fence (Mitchigan), the Deer, and the Hemlock Rivers.

Previous work in this area.—The chief interest in the area has been due to the occurrence of iron ores in the sedimentary rocks associated with the volcanics. The iron deposits first discovered in this region were those lying along the Paint River near Crystal Falls, just outside of the immediate area under discussion, and were briefly mentioned by Major T. B. Brooks in his report on the iron-bearing rocks of Michigan.[1] Apparently little attention was paid to the district for some time after this, except by the prospectors, who gradually advanced with their test pits to the north, until the deposits along the Michigamme to the northeast and at Amasa to the northwest were found.

In his report of work done on the Upper Peninsula between 1881–4, which has just appeared, Rominger[2] refers those iron deposits occurring along the Michigamme River in Township 43 N., Range 31 W., Section 4, and Township 44 N., Range 31 W., Sections 33 and 34, to the Huronian, corresponding to the rocks of the Quinnesec ore range, to which reference had been made in previous publications.[3] The volcanics were not recognized as such, but were called diorite.[4]

[1] Geol. Sur. of Mich., Vol. I., Part I, p. 182, 1873: he writes, "Too little is known about the Paint River district . . . . to enable me to give anything of interest regarding its geological structure. The Huronian rocks are extensively developed there, and contain deposits of hard hematite ore."

[2] Geol. Sur. of Mich., Vol. V., p. 32, 1895.

[3] Ibid., Vol. IV., p. 82, 1881.

[4] Ibid., Vol. V., p. 37.

The mining district of Amasa is of quite recent development, and as far as I am aware no attempt has thus far been made to refer the deposits to any definite geological horizon.

During 1892, Messrs. W. N. Merriam and H. L. Smyth, with their assistants, were engaged in tracing out the iron-bearing formation in this region. Smyth worked in the northeast along the Michigamme River, and Merriam west of the Michigamme River and southwest of the Deer River. When their work was finished the two areas were not connected in the north by about twelve miles, and a narrow belt separated the mapped areas to the south.

During the season of 1894, I was engaged, with the assistance of G. E. Culver and S. Weidman, in completing this area, preparatory to extending the work into the Menominee iron district. Many of the facts of the field occurrence mentioned in the following article were observed and recorded by Merriam and assistants, and were subsequently verified by my own observations of last season in a different portion of the area, and by visits to localities in the areas previously surveyed.

Succession.—A résumé of the ascending succession is as follows: The area considered is oval in outline, about twenty-five miles long and twelve miles wide, extending in a N.W.–S.E. direction (Pl. I.) The center of this oval is occupied by an elliptical area thirteen miles long by three miles wide, of the oldest rocks of the district, consisting of granite and gneiss, cut by numerous basic dikes. This is surrounded by a quartzose limestone formation, with an estimated thickness of 1500 to 2000 feet.[1] In places the quartz almost disappears and we get a limestone. In other places we have an almost pure quartzite. The formation disintegrates very rapidly, and to this fact can probably be attributed the lack of outcrops over the greater portion of the area which it is supposed to underlie. Overlying the limestone we find, both to the east and west of the ellipse described, a great series of volcanics with an average thickness of about 3000 feet. Their greatest development is to the west of the ellipse, where the average thickness is 4000 feet. It appears probable that these two areas

[1] H. L. SMYTH: Relations of the Lower Menominee and Lower Marquette Series in Michigan. Am. Jour. Sci., 3d Ser., Vol. XLVII., p. 217, January 1894.

are connected around the ellipse both to the north and south, forming a belt completely encircling it. The volcanics are in turn enclosed by a zone of sedimentaries, for the most part quartz-

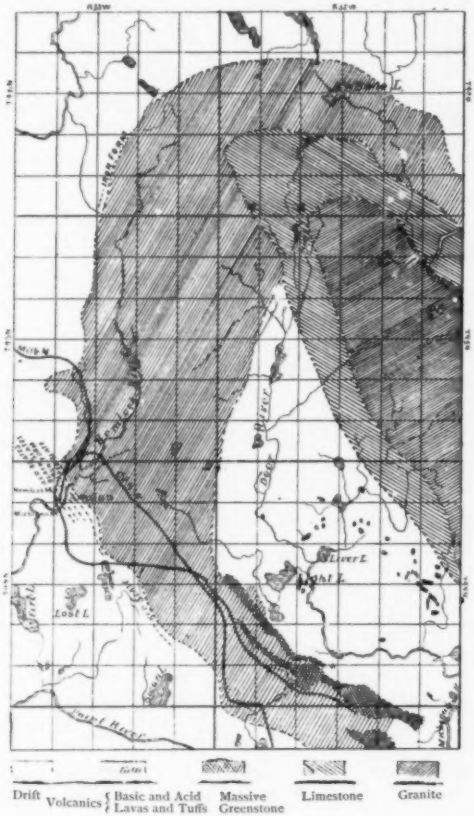


PLATE I.

Preliminary map of part of the Michigamme district. Scale 1 in to 4 miles.

ite and slate, which is throughout characterized by the greater or less amount of iron which it contains. It is known as the Michigamme jasper, from its typical development at Michigamme

Mountain.[1] Test pits are common where it outcrops, and at Amasa it contains iron in quantities sufficient to be mined. This series is also characterized by its marked magnetic properties. It was chiefly due to this property that it was found possible to connect the widely separated outcrops by means of the dip needle and of the dial compass.

The entire district is heavily covered with drift, showing in many places beautifully developed glacial topography. This mantle conceals so much of the country rock that the outcrops are very scarce, thus very greatly increasing the difficulties of the geologist.

Owing to the incompleteness of the work the structure of the area and the correlation of its rocks will be left for a future report. It can be stated, however, that the volcanics are of Huronian age.

Volcanics.—Those discussed in this paper lie in general to the west of the Archean core, and between Bone Lake on the north and Crystal Falls on the south. They are the rocks which predominate in, and are by far the most characteristic for, this district, the sedimentaries playing only a very subordinate rôle. The belt in which they are found varies in width from three-fourths to four and one-half miles. The apparent enormous thickness which this would give to the series in the widest part of the belt, since the dip of the rocks is about 75°, has been greatly increased by the minor crumplings and thrusts to which the series has undoubtedly been subjected. The very considerable thickness may be partly explained by supposing the volcanics to have accumulated in the immediate proximity of the vents from which they were ejected. If we accept an average thickness of 4000 feet, we will probably not overestimate it.

Since the flows are all now on edge, and erosion has left only isolated fragments of flows and accompanying tuffs, it is only possible to study them in cross section. Owing to this fact the topography is very rough, the elevations in most cases corresponding to the massive rocks, though thoroughly consolidated breccias form some of the highest hills. That these rocks are

[1] Loc. cit., p. 217.

true volcanics could not be doubted for a moment by any one seeing them *in situ* or even in hand specimens. They exhibit the vesicular character and flow structure of modern lavas, and interbedded with them we find great masses of breccia and tuff, composed of dense and scoriaceous fragments of rock similar in appearance to the rocks of the lava flows. A fact to be noted is that remarkably few undoubted dikes have been observed. This may be due to some extent to the disposition of the strata.

Both basic and acid igneous rocks are represented in the Michigamme district by lava flows and pyroclastic deposits. The basic volcanics comprise those altered pre-Tertiary equivalents of the basalts and andesites known as melaphyres and porphyrites. In the following pages they are called apobasalts and apoandesites. The acid rocks include originally holocrystalline porphyritic rocks, quartz porphyries, and devitrified equivalents of the rhyolites, which are here called aporhyolites.[1]

The apobasalts are by far the most common of the volcanic rocks. Their colors are various shades of green, dark olive-green prevailing. Upon weathering the green rock is usually covered by a thin crust, in which gray, brown, and even pinkish tints prevail.

The lavas vary in coarseness from dense aphanitic rocks to those which are medium-grained. No coarse-grained rocks are found among the interbedded flows and tuffs.[2] Some of the most characteristic volcanics are fragments in the pyroclastics. The most constant volcanic characteristic is the presence of a well-marked amygdaloidal structure, the rounded or more less irregular shaped amygdules ranging from those of almost microscopical size up to others larger than a pigeon's egg. Some of the rocks are so full of these vesicles as to be truly scoriaceous.

[1] F. BASCOM: The Structures, Origin, and Nomenclature of the Acid Volcanic Rocks of South Mountain. JOURN. GEOL., Vol. I., No. 8, p. 828, Nov.–Dec. 1893.

[2] In the southern portion of the area occur great continuous masses of coarse-grained rocks, which are undoubtedly closely related to the volcanics. At the present stage of the investigation it is, however, undecided just what this relation is. It is presumed that they represent great fissure flows, with which eruptive activity here began, and which were subsequently followed by the extrusion of the thinner lavas and ejection of the lapilli and ashes forming our present breccia and tuff deposits. Their general distribution is shown on the accompanying sketch map, Pl. I.

Thin sections of the rock show a characteristic ophitic structure, with in places a flow structure around the amygdules brought out by the feldspar microlites. The angular interstices between the well preserved lath-shaped crystals are filled by irregular pieces of fibrous green hornblende, with here and there epidote, zoisite, less chlorite, and grains of titanite, the result of the alteration of the original augite and titano-magnetite, and also of any original vitreous base which may have been present. The presence of a base is indicated by the presence of chloritic material between some of the feldspars, seemingly the alteration product of the base in which the crystals were imbedded. Moreover the sharply bounded walls of the amygdules may indicate the former presence of glass.[1] Olivine has in no case been observed. The feldspar is very fresh, only beginning to become slightly turbid through development in it of a few grains of epidote and flakes of chlorite. Rarely does any original magnetite remain, and in such cases the rock is very noticeably darker.

Apoandesite.—The apoandesites include those rocks which, while intimately associated with and very closely related to the apobasalts, differ from them in their porphyritic habit, having labradorite as phenocrysts.

In thin section the large automorphic phenocrysts of slightly altered plagioclase lie in a very fine grained matrix, composed of long slender feldspar microlites separated by crystals of magnetite,—though in most cases it has entirely disappeared,—and the alteration products of the original augite and base, fibrous green hornblende, epidote, zoisite, chlorite, and brownish grains of a mineral which has a higher single and double refraction than the epidote, and is presumed to be titanite. Measurements made against the twinning plane of the plagioclase phenocrysts give an average extinction angle of 25°, indicating the feldspar to be labradorite.

The character of the microlites I have not been able to determine with sufficient accuracy. The alteration which most of them have undergone makes the task of searching for suitably

[1] J. J. SEDERHOLM: Studien über archæische Eruptivgesteine aus dem südwestlichen Finnland. Tsch. Mit. XII., p. 113. 1891.

oriented and sufficiently fresh sections upon which to make measurements an exceedingly tedious one. The rocks frequently show a flowage structure caused by the parallel arrangement of the microlites around the phenocrysts and amygdules. The minerals of the andesite have suffered the same changes as those of the basalts. Andesitic fragments are also very common in the tuffs, although in no place do we have a true andesite tuff or breccia.

As is seen from the description of the freshest and most characteristic of the basic volcanics, the mineral constituents have undergone very far reaching alterations, the result of which has been to produce most commonly epidote, zoisite, fibrous green hornblende, chlorite, and less quartz, feldspar and calcite. More advanced alteration results in rocks very similar to the basalts and andesites as described above, in which, however, the feldspar crystals are replaced by chlorite and epidote, the feldspar shapes being retained. In such cases the ophitic structure shows nicely in ordinary light, but between crossed nicols the feldspars break up into aggregates of chlorite and epidote, completely concealing the characteristic structure of the rock. The very fine grained lavas undergo the same alteration, producing a very tough light green rock which does not show at all the structure of an eruptive rock, as they are frequently found free from amygdules. In the very fine grained rocks the production of so much epidote and titanite in minute grains, by their high single refraction, causes the rock to appear almost opaque in thin section.

In addition to these changes, which have been for the most part merely the replacing of one mineral by another, the rocks have been subjected to considerable pressure and shearing, which have in many places given them a more or less perfect schistosity. In such cases the flattening of the amygdules is especially noticeable.

The amygdules are filled by nearly the same minerals as those which occur secondarily in the rock mass itself. Arranged in order of frequence of occurrence they are as follows: Epidote, zoisite, chlorite, quartz, calcite and feldspar. The non-

occurrence of zeolites is very noticeable, since they are so common in the altered modern basalts, and also occur in basalts as old as those of South Mountain[1] and of Keweenaw Point.[2]

The amygdules usually stand out well from the body of the rock when filled with infiltrated products or when weathering has left them empty, giving the rock, in the first case, from a short distance, the appearance of porphyry, in the second, a decidedly scoriaceous look.

A columnar structure so common in the modern equivalents of such rocks is noticeably absent. A spheroidal structure, however, having the same appearance as that described by Lawson,[3] Williams[4] and also by Cole[5] and Gregory,[6] is quite common in the lavas. It was in no case observed in the fragmental deposits.

The breccias and tuffs.—Flow breccias formed of angular basalt fragments imbedded in a matrix of the same material are found, but since they preserve the main character of the ordinary basalt flows which have just been described, they will not be discussed in the following passages. The pyroclastics are very common and quite characteristic, the characters of the beds being best shown on the weathered surfaces. On these the light grayish green fragments of varying size and more or less

[1] G. H. WILLIAMS: The Volcanic Rocks of South Mountain in Pennsylvania and Maryland, Am. Journ. Sci., 3d Ser., Vol. LXIV., p. 491, 1892.

[2] RAPHAEL PUMPELLY: Paragenesis and Derivation of Copper and its Associates on Lake Superior, Am. Journ. Sci., 3d Ser., Vol. II., p. 188, 1871; also Geol. Sur. of Michigan, Vol. I., Part II., pp. 19–46, 1873; Geol. of Wisconsin, Vol. III., p. 31, 1880.
R. D. IRVING: The Copper-bearing Rocks of Lake Superior, Mon. V., U. S. Geol. Sur., p. 89, 1883.

[3] A. C. LAWSON: Report on the Lake of the Woods, Geol. and Nat. Hist. Sur. of Canada (New Ser.), Vol. I., pp. 52–3, 1885.

[4] G. H. WILLIAMS: The Greenstone-schist Areas of the Menominee and Marquette Regions of Michigan, Bull. U. S. Geol. Sur., No. 62, p. 166, Fig. 26, 1890.

[5] G. A. J. COLE and J. W. GREGORY: On the Variolitic Rocks of Mt. Genevre, Q. J. G. S., Vol. LXVI., p. 311, Fig. 4, 1890.

[6] J. W. GREGORY: On the Variolitic Diabase of the Fichtelgebirge, Q. J. G. S., Vol. LXVII., p. 48, Fig. 2, 1891.
In these last two papers the illustrations of the structure are especially characteristic.

angular shape stand out well from the brownish red matrix. A fresh surface shows the fragments to be light green, and the cement a darker green. The fragments vary in size from bowlders to minute ones which fill in the interstices between the larger ones and thus serve to make the mass compact. They are for the most part not amygdaloidal, but very dense, although those which are amygdaloidal and even scoriaceous do occur mixed with the dense fragments, and in places equal them in quantity. The basalt and andesite appears to be equally well represented in the pyroclastics.

These deposits show in places a well-developed banding caused by interbedding of layers in which coarse and fine fragments alternately prevail, illustrating well the varying intensity of the volcanic discharges. Gradation could also be traced from the coarse breccias to the delicately banded portions which are exactly analogous to the fine sand and ash beds of the modern Tertiary and recent volcanoes. These fine sand and ash beds are not, however, composed of crystal elements, but as far as the observations go are composed solely of very fine rock fragments. In such places the difference between the thickness of the ash beds and of the tuff is naturally very great. The average thickness of the ash beds observed was about three feet. In the same exposure the tuffs are from 50 to 100 feet thick. The thickness of the more massive layers could not be determined. Especially good opportunities for observing the varying relations between tuff and ash beds is offered by the third cut on the Milwaukee & Northern Railway west of Balsam, Michigan; south of the lake in Sec. 5, Township 43 N., Range 32 W., Michigan, the tuff and lava flows are very well exposed. The pyroclastics seem to predominate in the northwestern portion of the region in the neighborhood of Amasa.

It is almost needless to state that these pyroclastics have undergone a great amount of alteration, and yet the thin sections of some of the rock fragments are the freshest and prettiest seen. The changes which have taken place were purely of a metasomatic nature, and as water is the chief agent in such changes, these began in the interstices. In the case of the frag-

ments, then, the alteration would naturally proceed from the outside inwards, and ordinarily at an equal rate all around the fragment, following its contours. In this way we get zones of different mineralogical composition, depending upon degree of alteration. This secondary zonal structure can be observed in almost any of the sections made from the breccias, but the concentric structure of many of the fragments is especially well shown on large weathered exposures.

The alterations which the fragments have undergone are the same which have taken place in the basalt and andesite flows, and the prevailing light green color of the fragments has resulted from the production of the same light colored secondary minerals. As in the lava flows, some of the denser rocks have become almost opaque, and have usually a lighter green color than the less altered fragments. An especially well preserved fragment shows the perfectly fresh feldspars lying in a dark brown isotropic glassy base. Where this is very thin, globulitic devitrification products can be seen, and there also the base is no longer isotropic, but very faintly doubly refracting.

In addition to the rock fragments a few rare ones of large plagioclase crystals were found in a tuff, and also in one case a fragment of a violet brown augite, the only specimen of fresh augite thus far found in any of the volcanics.

As was stated above, the cement is usually darker in the hand specimen than the pieces of rock imbedded in it. Under the microscope this condition is found to be reversed. The fragments as described above remain opaque or nearly so, whereas the cement becomes transparent. It is found to be composed for the most part of the same secondary minerals as occur in the fragments,—epidote, zoisite, fibrous green hornblende, chlorite, quartz, feldspar, and a great deal of brownish titanite in rounded aggregates and grains, never in crystals. Calcite is less common than one would expect, but in some cases it forms almost exclusively the cement. Muscovite is rare. Zeolites were found to be wanting in the tuffs as well as in the lavas.

The exact mode of deposit of these basaltic and andesitic breccias and tuffs, that is, whether they are true æolian deposits

or are masses which were brought together by the action of water, will in some cases have to remain undecided. It is supposed that the major portion is a true æolian pyroclastic deposit.

That certain of the pyroclastics have, however, been deposited through the mediation of water is shown by specimens from 50 N., 1270 W., Sec. 34, Township 45 N., Range 33 W., near Amasa, which is a true basalt conglomerate. In these rocks the pebbles are decidedly rounded, but consist of characteristic volcanic fragments, as is shown by the amygdaloidal structure. The most of the pebbles are thoroughly impregnated with iron in the form of magnetite, giving them a black color. Under the microscope the feldspar skeletons are occupied now by chlorite and muscovite, and the portions between the skeletons is a mass of magnetite grains, in rare cases with a little hematite.

The cement is chiefly calcite and quartz in which is developed a large amount of chlorite and muscovite, and in which occurs also magnetite, though the last is more common in the fragments. No pieces of undoubted sedimentary rocks were observed in the conglomerate.

The acid volcanics.—These play a very subordinate rôle, occurring in such small quantity as to make it impossible without very great exaggeration to place them on the accompanying map. Their relations to the basic volcanics are obscured by lack of exposures, but in no case were they observed as dikes in the latter. The trend of the ridges formed by the acid rocks agrees with the general strike of the banding in the basic tuff deposits, and they are presumed to represent acid flows and tuffs interbedded with the basic lavas and pyroclastics.

On fresh fracture they are black, grading with advancing alternation into chocolate brown to reddish rocks. The weathered surface varies from white to reddish. This has in one case brought out very well the fluxion banding of the rock.

Their structure is very pronouncedly porphyritic, the quartz and feldspar crystals standing out plainly from the groundmass, which is usually dense with somewhat resinous luster. Under the microscope they are found to be typical quartz porphyries,

with here and there an oval area representing amygdaloidal cavities, which are now filled with secondary quartz. The phenocrysts are for the most part corroded dihexahedral crystals of quartz, with less commonly phenocrysts of plagioclase and orthoclase. These lie in a fine grained groundmass, which is holocrystalline and composed of feldspar and quartz, with some zircon in small crystals, and here and there magnetite.

The quartzes average perhaps the size of a small pea, and hence are macroscopically quite plain. They frequently stand out on the fractures and show their crystal form, and in other cases we see the angular cavities out of which they have fallen. In the thin sections the crystal contours are seen to be more or less rounded, with here and there embayments of the groundmass projecting into them. The crystal form is, however, clearly marked. In some cases the individuals have been broken before the cooling of the magma, the fragments being seen to conform to one another. That some of them have been subjected to pressure is shown by the slight undulatory extinction and by the separation of the black cross of uniaxial minerals into hyperbolæ. The quartzes are quite clear though they contain some inclusions of groundmass and numerous liquid inclusions in which there are dancing bubbles. The liquid inclusions have very commonly an hexagonal form, corresponding to the contours of the enclosing quartz. The possession of an imperfect rhombahedral cleavage is very noticeable in a number of the quartzes, and especially those which, being on the edge of a section, are very thin. (Fig. 1.) The quartz phenocrysts in all the porphyries, with the exception of those from two localities, are surrounded by zones of varying widths, considerably lighter than the remainder of the groundmass. They have the same optical orientation as the phenocrysts, and therefore extinguish with them. In those sections in which the zones occur they are found around every quartz individual.

The feldspars present are orthoclase and plagioclase, the latter apparently predominating. They occur usually in rounded crystals, very rarely in grains with irregular more or less angular contours. They are always altered, and have associated with

them the secondary products calcite, epidote, muscovite and chlorite, and by their alteration alone could be readily distinguished from the clear quartz. Moreover, the quartz and feldspar can be distinguished at a glance in certain sections by the occurrence of the aureoles around the quartz. In no case was an aureole observed to occur around a feldspar.

No ferro-magnesian minerals are found in the porphyry, nor is their former presence indicated by any secondary product. The secondary minerals contained in the porphyries are chlorite, calcite, epidote, muscovite and biotite.

FIG. 1.— Micro-drawing of quarts, multiplied 47 diameters, showing cleavage.

The microscopic character of the dense groundmass varies according to the mode of association of its two chief elements, the quartz and feldspar, and we thus get the varieties of prophyry named after the resulting structure.

The commonest variety is the quartz-porphyry with micrographitic groundmass (Porphyre granulitique of Michel-Lévy). A second variety is the quartz prophyry with micropoikilitic[1] groundmass. The micrographitic structure is too well known to warrant a description of it here. The micropoikilitic structure which is present in the porphyries seems, however, to be a phase which is somewhat different from any thus far described or figured, and therefore deserves to be described more at length.

[1] J. P. IDDINGS: The Eruptive Rocks of Electric Peak and Sepulchre Mountain. 12th Ann. Rep. U. S. G. S., p. 589.

G. H. WILLIAMS: On the Use of the Terms Poikilitic and Micropoikilitic in Petrography. Journ. of Geol., Vol. I., No. 2, pp. 176–9. Feb.–Mar., 1892.

It is hoped that an opportunity for working this up more in detail will present itself in the near future. In the meantime I shall rely on the following brief description, and more especially upon the accompanying photographs (Pl. II., Figs. 1 and 2), to

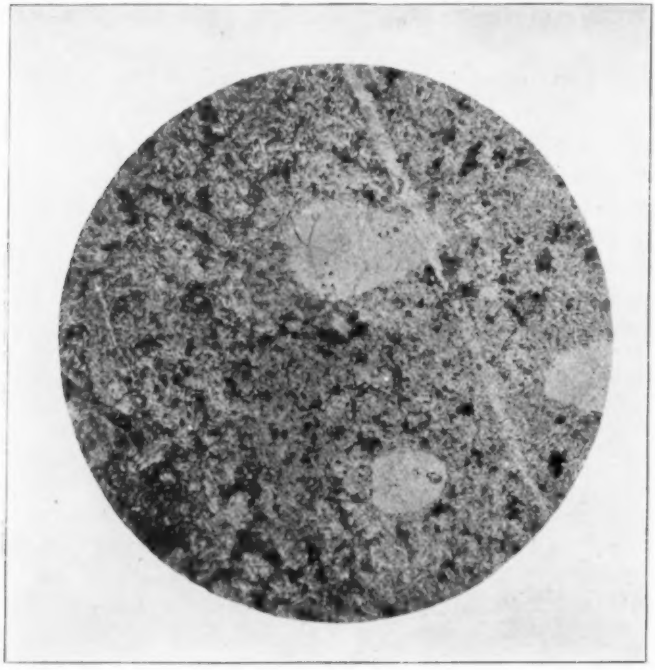


PLATE II.

FIG. 1. — Micropoikilitic quartz-porphyry, showing the peculiar structure of the groundmass in ordinary light. Magnified 18 diameters.

give a correct idea at least of the appearance of it under the microscope.

The structure of the groundmass can be seen even in ordinary light; it is brought out better when the field is partly shaded, so as to bring out the varying relief of the minerals (Pl. II., Fig. 1); and best of all between crossed nicols (Pl. II., Fig. 2). The

groundmass is then seen to be made up of reticulating areas of clear quartz, in which lie imbedded irregular pieces of feldspar. The quartz occurs in irregular areas, extending in all directions in long slender or short broad portions, these extensions jointing again farther on or being connected by crosspieces, all enclosing irregular pieces of feldspar. The network of quartz is best brought out when it shows its highest polarization color, as then the feldspar is for the most part dark. The pieces of feldspar in such a quartz area do not all have the same orientation, as is shown by the varying extinction angle, though a goodly number do extinguish simultaneously. The boundaries between the quartz areas, which can only be seen between crossed nicols, are bridged over in some instances by the pieces of feldspar. The main point is that the quartz is the base, the feldspar imbedded in it, and that in those uniformly polarizing quartz areas the included feldspar pieces show varying optical orientation. Therefore, the structure is not a true micropegmatite, according to the generally accepted definition.

Around the porphyritic quartzes there is a zone having exactly the same structure as the groundmass, and the connection of the quartz of the crystal and that of the zone is well shown by the continuation of the quartz with it, and the consequent agreement in orientation (Pl. II., Fig. 2). The lack of a uniform optical orientation of the feldspar fragments is made especially apparent when the quartz is cut perpendicular to the c axis, and consequently remains dark between crossed nicols. Under the above circumstances we see certain feldspar grains polarizing in the zone around the quartz, and as the stage revolves new fragments lighten as those which polarized in the previous position of the stage become dark. The feldspar seems to have no effect upon the groundmass. It certainly is never surrounded by zones, as is the quartz. An explanation for these micropoikilitic zones should, then, also explain the structure of the groundmass.

The irregular areas in the groundmass are certainly in some cases, and probably in most cases, the result of tangential sections through one of these micropoikilitic zones surrounding the

quartz phenocrysts. The micropoikilitic structure has been held in some cases to be of secondary origin.[1] I can find, however, no evidence whatsoever which indicates a secondary origin for the structure in these rocks. On the other hand, there is like-

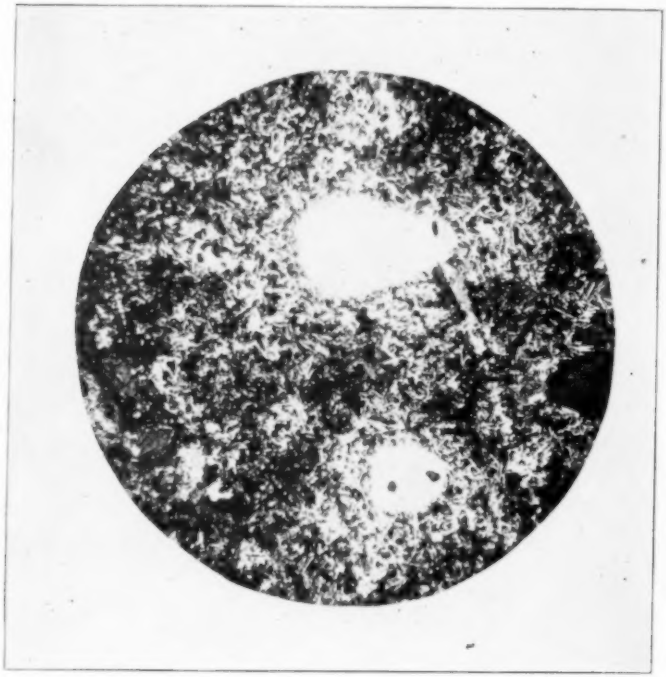


PLATE II.

FIG. 2.—The same section in polarized light, showing the micropoikilitic zone around the quartz phenocrysts. The irregular small dark spots in the white network of quartz are the feldspar grains. Magnified 18 diameters.

wise an absence of evidence proving unquestionably its primary character. Rather, however, than accept an explanation which

[1] R. D. IRVING: The Copper-bearing Rocks of Lake Superior. Mon. V., U. S G. S., p. 99, 1883.

F. BASCOM: Structures, Origin and Nomenclature of the Acid Volcanic Rocks of South Mountain. JOURN. OF GEOL., Vol. I., No. 8, p. 816. Nov.-Dec., 1893.

requires the production of secondary quartz and the influencing of it by the phenocrysts—similar to the frequently described oriented enlargements of quartz grains in sandstones and quartzites—it seems more natural to suppose that after the crystallization of the phenocrysts when the lava was extruded, there began a rapid crystallization of the mineral elements from the remaining magma, resulting in the production of the feldspar in very imperfect crystal individuals, with the quartz as a cement, the orientation of the latter being determined by the quartz phenocrysts. In other words, the quartz continued to grow, retaining its previous orientation, its continuity interrupted, however, by the feldspar grains.

Aporhyolites.—Intimately associated with the above described quartz-porphyries we find rocks very similar in every way to them macro- and microscopically, as far as the mineral constituents are concerned, so that the description of the quartz-porphyries will answer for the aporhyolites. It is only upon the presence of a well-developed perlitic parting, which is taken as indicating the presence of an original glass, that they are classed with the rhyolites. These perlitic cracks are now well brought out in ordinary light by the chlorite flakes found along them. Between crossed nicols these disappear and the groundmass resolves itself into a fine-grained mosaic of quartz and feldspar.

Tuffs.—The only acid tuff found is formed from the rhyolite. On its weathered surface it is white and exceedingly rough. This roughness is due to great extent to the weathering and subsequent leaching out of the feldspar, giving the rock an almost scoriaceous appearance. Its brecciated character is admirably shown by the difference in weathering of the fragments and cement. The latter being very siliceous is more resistant than the rhyolite, and stands out from the rock as white ridges marking the outlines of the fragments. Under the microscope in ordinary light the tuff is seen to be composed of angular fragments of rhyolite, in which is a well developed perlitic parting, and of angular pieces of quartz and feldspar, both orthoclase and plagioclase, held together by a cement of quartz.

Conclusions.—It will be seen from the foregoing preliminary

description of the volcanic rocks of the Michigamme district, that in this district we find well preserved evidence of true volcanic activity, in the presence of amygdaloidal lava flows and volcanic breccias and tuffs. These are comparable in every way in their external appearance to the ejectamenta of Tertiary and recent volcanoes. Like these, also, the rocks vary from very basic (basalts) to those containing a high percentage of silica (rhyolites).

That they have undergone more or less alteration as a result of their age alone was to be expected, but it is remarkable that in spite of their age and the dynamic action to which they must also have been exposed—since we now find the flows on edge—they should remain so fresh and retain so perfectly their characteristics as volcanic rocks. The age of these deposits has been determined to be Huronian.

This adds one more to the localities in America in which the occurrence of associated basic and acid volcanics of pre-Cambrian age have been described microscopically.[1]

That such pre-Cambrian volcanics are by no means rare in

[1] M. E. WADSWORTH: Notes on the Min. and Pet. of Boston and Vicinity. Proc. Bos. Soc., Nat. Hist., Vol. XIX., pp. 217–237. 1877. Geology of the Iron and Copper District. Bull. Mus. Comp. Zoöl., Vol. VII. (Geol. Ser. 1), No. 1, p. 157. 1880. Did not observe the felsitic porphyries interbedded with the basic rock on Keweenaw Point, and described later by Irving, but described the conglomerates made up of trachytic and rhyolitic fragments (p. 120).

J. S. DILLER: The Felsites and their Associated Rocks North of Boston. Bull. Mus. Comp. Zoöl., Vol. VII. (Geol. Ser. 1), No. 2; and Proc. Boston Soc. Nat. Hist., Vol. XX., pp. 355–368. January 1880.

R. D. IRVING: The Copper-bearing Rocks of Lake Superior. Mon. V., U. S. G. S. 1883.

ANDREW C. LAWSON: Report on the Geology of the Lake of the Woods Region. Geol. and Nat. Hist. Sur. of Can. (New Ser.), Vol. I., CC. 1885; and Geology of the Rainy Lake Region. Geol. Sur. of Can., 1887–8, F., p. 182.

E. HAWORTH: A contribution to the Archean Geol. of Missouri. Am. Geol., Vol. I., pp. 280–297, 363–382. 1888.

T. G. BONNEY: Notes on a part of the Huronian Series in the Neighborhood of Sudbury, Can. Q. J. G. S., Vol. XLIV., pp. 32–45. 1888.

G. H. WILLIAMS: In Bell: On the Sudbury Mining District. Geol. Sur. of Can., 1890–1, F. App. L, pp. 55–82. The Greenstone-schist Areas of the Menominee and Marquette Regions of Mich. Bull. 62, U. S. G. S., 1890. The Volcanic Rocks of South Mountain in Pennsylvania and Maryland. Am. Journ. of Sci., 3d Ser., Vol. XLIV., pp. 482–496. December 1892.

America can be seen by referring to the brief reports of their occurrence in the Eastern townships of Quebec and in New Brunswick and Nova Scotia, which have been made by Bailey,[1] Ells,[2] Fletcher,[3] Matthew,[4] Selwyn,[5] and Low.[6]

Similar areas are known in Newfoundland, especially from the peninsula of Avalon, through the reports of Howley,[7] Jukes,[8] and Murray.[9]

Somewhat younger are the acid and basic volcanics described by Shaler[10] from Maine, Matthew[11] from New Brunswick, and Bayley[12] from North Haven, Maine.

Basic volcanics alone of Huronian age have been described from the Penokee area, Wisconsin, by C. R. Van Hise,[13] and to judge from Bell's[14] reports, occur in considerable quantity to the north of Lake Huron and around the shores of Hudson's Bay.

[1] Can. G. S., 1870–1, pp. 13–240; 1877–8, DD.; 1878–9, D.; Proc. Am. Asso. Adv. Sci., 29th meeting, 1880, pp. 415–421.

[2] Can. G. S., Vol. II., J., New Ser., 1886; 1882–4, E.; 1879–80, D.; 1877–8, D.; 1878–9, D.

[3] Can. G. S., Vol. II., P., New Ser., 1886.

[4] Can. G. S., Vol. II., Rep. 3, pp. 387–391, 2d Ser., 1888. Q. J. G. S., London, Vol. XXI., pp. 422–434, 1865. Can. G. S., 1870–1, pp. 13–240; 1878–9, D.

[5] Proc. and Trans. Royal Soc. of Can. for 1882–3, Vol. I., Sec. 4, pp. 1–13.

[6] Can. G. S., 1882–4, F.

[7] G. S. of Newfoundland for the year 1881, pp. 6–23.

[8] Ibid., 1839–40, pp. 160.

[9] Ibid., pp. 111–136. G. S. 1872, pp. 279–297.

[10] Prel. Rep. on the Geol. of Cobscook Bay. Am. Journ. Sci., 3d Ser., Vol. XXXII., p. 40. 1886. Geol. of Mount Desert. Ann. Rep. U. S. G. S., Vol. VII., p. 1042. 1889.

[11] Rep. on the Upper Silurian and Kingston (Huronian) of Southern New Brunswick. Geol. Sur. of Can., Rep. 1877-8 E.

[12] The Spherulitic Volcanic Rocks of North Haven, Maine. Bull. Geol. Soc. of Am. Vol. VI., 1894, p. 474.

[13] IRVING AND VAN HISE: Penokee Iron-bearing Series of Michigan and Wisconsin. Mon. 19, U. S. G. S., p. 410. 1892.

[14] Can. G. S., Reps. for 1876–7, p. 213; 1877–8 C.; 1779–80 C. The Geol. and Economic Minerals of Hudson's Bay and Northern Canada. Proc. and Trans. Royal Soc. Can., Vol. II., Sec. 4, p. 241. 1884.]

Wadsworth [1] has also described basic volcanics from Newfoundland, and Walcott [2] has mentioned their occurrence in the Algonkian of the Grand Canyon series, stating that according to Iddings' examination they are true doleritic basalts.[3]

The volcanics of the Michigamme district can be closely paralleled with similar rocks in Finland and Sweden, described in detail with full recognition of their volcanic origin by J. J. Sederholm [4] and by Otto Nordenskjöld.[5]

Numerous descriptions of such occurrences have appeared within the past years from the English geologists,[6] and all of them have recognized in full their identity with the younger volcanics, and have usually applied the names in use for the younger to their older equivalents. Wadsworth [7] was the first in America to follow and advocate this simplification of the nomenclature. In 1892, Williams' [8] article upon the South Mountain Volcanics appeared.

In all other countries the generally accepted nomenclature has been a dual one, one term for a pre-Tertiary rock and another

[1] Notes on the Rocks and Ore Deposits in the Vicinity of Notre Dame Bay, Newfoundland. Am. Jour. Sci., 3d Ser., Vol. XXXIII., pp. 94–104. 1884.

[2] Algonkian Rocks of the Grand Canyon of the Colorado. JOUR. GEOL., Vol. III., No. 3, p. 325, April–May, 1895.

[3] Loc. cit., p. 330.

[4] Studien über Archæische Eruptivgesteine aus dem Südwestlischen Finland, Tsch. Min. and Pet., Mitt. XII., pp. 98–142. 1891.

[5] Über Basische Ergussgesteine aus dem Elfdalener Porphyrgebiet. Bull. Geol. Inst. Univ. of Upsala, Vol. I., No. 2, pp. 105–112. 1893. Über Archæische Ergussgesteine aus Småland. Ibid., pp. 133–255.

[6] For references to their papers see GEIKIE: Anniversary Address, Q. J. G. S., Vols. 47 and 48, 1891–2. Most of their papers are to be found in the files of the Q. J. G. S. and Geol. Mag. and Memoirs of Geol. Sur. of Great Britain.

[7] Notes on the Min. and Pet. of Boston and Vicinity. Proc. Bos. Soc. Nat. Hist., Vol. 19, p. 236, 1877; ibid. 1878, pp. 309–316.

On the Classification of Rocks. Bull. Mus. Comp. Zoöl., Vol. V., No. 13, pp. 275–287. 1879.

Geol. of the Iron and Copper Districts. Bull. Mus. Comp. Zoöl., Vol. VII., Geol. Ser., No. 1, p. 157, 1880.

Prel. Descr. of the Peridotites, Gabbros, Diabases, and Andesites of Minn. Geol. and Nat. Hist. Sur. of Minn., Bull. No. 2, 1887.

[8] Am. Jour. Sci., 3d Ser., Vol. XLIV., p. 486. 1892.

for its post-Tertiary equivalent,—in spite, too, of the fact that the great resemblance between such rocks has been frequently emphasized.

In a paper published in 1893, upon the acid rocks of the region described in the preliminary paper by Williams,[1] Miss Bascom[2] proposes "to call the acid volcanic rocks whose structures prove them to have once been glassy, *aporhyolites*, while those which have consolidated at a sufficient depth to secure a holocrystalline groundmass should be termed *quartz-porphyries*, whether ancient or modern lavas," the moment which is to determine the use of the name being the "specific alteration known as devitrification." Thus, using the term rhyolite in its present sense, extended however so as to include its pre-Tertiary equivalents, we may have rhyolites of all ages, and likewise aporhyolites of all ages. It was proposed also to apply the prefix *apo* to all other devitrified rocks.

Independently of Miss Bascom, and shortly after her paper appeared, Nordenskjöld proposed, before the Students' Association of Natural Science of the University of Upsala,[3] the names *eorhyolite*, *eobasalt*, etc., for the old equivalents of the rocks known as rhyolites, basalts, etc. It appears to me preferable to use the nomenclature proposed by Miss Bascom, both on the grounds of priority and of expressiveness, as the name indicates in what condition we will find the rocks, whereas the names proposed by Nordenskjöld would merely mean an addition to petrographical literature of new names to express conditions which are already expressed by names at present in use. Thus under eorhyolites we have rocks placed in opposition to the neorhyolites, which as a result of their age are probably very much altered, though this condition is not necessary for the correct application of the term as I understand it. It is possible that at some time there may be found an insignificantly altered rock which must be classed with the eorhyolites. On the other hand, we will undoubtedly

[1] Loc cit.

[2] The Structures, Origin, and Nomenclature of the Acid Volcanic Rocks of South Mountain. JOUR. OF GEOL., Vol. I., No. 8, p. 829. Nov.–Dec., 1893.

[3] Loc. cit., p. 292, meeting on November 18, 1893.

find rocks which are apo- but not eorhyolites. Moreover, the idea of time is inseparably connected with the names proposed by Nordenskjöld, and it is very desirable to eliminate this altogether from petrographical nomenclature. Again, unless there is to be a decided gain from the use of new terms, we might just as well continue to use the terms which have been so long in use, as felsite, etc., as these already imply a difference in age and condition of preservation. According to Miss Bascom, we can consistently class devitrified rocks, whether pre-Cambrian or recent, under aporhyolites and apobasalts, and their fresh equivalents likewise, whether pre-Cambrian or recent, under the accepted term rhyolite, basalt, etc.

J. MORGAN CLEMENTS.

MADISON, WIS.,
May 29, 1895.

THE INFLUENCE OF DÉBRIS ON THE FLOW OF GLACIERS.

THE behavior of ice under various conditions is frequently illustrated by experiments with pitch or other similar viscous fluids or plastic solids. If sand or other similar substance is distributed through pitch its plasticity will be reduced. When sufficient sand is added, the pitch will no longer flow under conditions that will cause clear pitch to readily change its shape. The reason for this is manifest; by mingling a rigid substance with one that is plastic the rigidity of the latter will be increased. As the percentage of rigid material increases the compound substance acquires more and more of its characteristics. Let us apply this principle to glaciers.

Ice under pressure behaves as a plastic solid. When a mass of ice, unsupported at the sides, is sufficiently large, it will change its shape of flow under the influence of its own weight. Although objections have been raised to each of these propositions, I shall for the present consider them demonstrated.

The study of glaciers, especially of the Alpine type, has shown that they flow after the manner of plastic solids. That is, there is a differential motion of molecules, or of particles, throughout the mass. In most instances, it seems safe to assume no two points, in a cross section of a glacier, will move at the same rate for any considerable time.

If we conceive of a glacier composed of clear ice moving at a given rate, and introduce débris — earth, sand, stones, bowlders, etc. — into it, without altering other conditions, the effect will be to decrease the rate of flow, since rigid substances are added to one that is plastic. If we gradually increase the percentage of débris, the ice becomes less and less plastic and finally acquires such rigidity that under the conditions normally influencing the movements of glaciers, it will cease to flow. If the débris instead of being uniformly commingled with the ice, is introduced irreg-

ularly, local changes in the rate of flow, and even local stagnation may be produced.

Stating this principle in the form of a proposition we have: The rate of flow of glacier ice, under given conditions, will depend on the percentage of débris commingled with it, and be least when the percentage is greatest. The nature of the débris, whether coarse or fine, smooth or angular, etc., will modify the result, but this need not be considered at present.

I shall attempt to indicate briefly the bearings of this principle in explaining certain glacial phenomena. What follows, however, is of the nature of suggestions to glacialists, rather than an effort to discuss the various problems touched upon.

Glacial erosion and subglacial deposition.—In the upper portion of a mountain valley that has been occupied by a glacier, as for example, Bloody Cañon, California,[1] the grade is frequently steep and the rocks intensely glaciated and but lightly covered with débris; lower down in the same valley, the grade decreases, and the bottom is deeply filled with débris that was deposited beneath the former glacier. In such an instance, the rate of flow of the former glacier was greatest in the upper portions of its courses and decreased down stream. In the upper portions also, the percentage of débris in the basal layer of ice was least and increased toward the extremity of the glacier. The swifter current and light change of débris in the upper portion of the glacier would favor erosion; while farther down its course a decrease in the rate flow, especially of the basal portion, would result both from loss of grade and also because of an increase in the percentage of contained débris. The débris-charged ice in contact with the rocks would be retarded and when the percentage of foreign material in it became sufficient would cease to flow. The heavily charged and stagnant bottom layer would increase in thickness as more débris was brought from up the valley or descended through crevasses and moulins in the ice. When the ice finally melted the débris accumulated in its basal portion would be left as a ground moraine.

The increase in rate of flow, in the instance above cited, from

[1] Eighth Ann. Rep. U. S. Geol. Surv. 1886–7, pp. 337–340.

the densely charged bottom layer to the clearer ice vertically above, might be gradual or abrupt, according as the percentage of débris decreased gradually upwards or had a sharply defined upper limit. When the change was abrupt, a plane of shear might be established. Whether a glacier charged at its base with débris, shall erode or deposit at a given locality depends on its rate of flow. The rate of flow is controlled by several factors, one of the most important being the percentage of débris contained in the ice. If the débris-charged ice in contact with the rocks beneath moves at all it will cause abrasion; if so heavily charged with débris, however, that it is rigid under the forces to which it is subjected, it will remain stationary and not only cease to erode but protect the rocks beneath, and lead to the accumulation of débris. A glacier may, therefore, erode in one portion of its course and in another portion accumulate débris in its stagnant bottom layer. Also, a decrease in the rate of flow may cause débris-charged ice to stagnate at a locality where erosion was previously in progress; while an increase in the rate of flow might lead to the removal of a previously stagnant layer.

If a glacier occupies a valley in which there is a change from a precipitous to a gentle slope, the rate of flow on the precipitous slope, other conditions being the same, will be greater than below, and may be sufficient to carry forward an amount of débris which would cause stagnation when the more gentle slope was reached. A glacier might, then, erode the rocks over which it passed in one portion of its course and farther on, accumulate débris in its basal portion so as to cause stagnation, without an increase in the amount of foreign material carried. Whether a glacier shall erode or deposit, depends, therefore, on a ratio between strength of current and the percentage of débris in its basal portion.

Clear ice in flowing over ordinary rocks has but slight if any power to abrade them. If débris of the kind commonly present in glaciers, is added to the ice, other conditions remaining the same, its erosive power will be increased until the percentage of débris is sufficient to materially check the flow, and will then decrease as

motion becomes less and less, and finally cease when stagnation results. The conditions most favorable for abrasion seem to be when the bottom layer of a glacier is lightly charged with small, hard and angular rock fragments. Other factors than those just mentioned, however, influence the abrasive power of glaciers; as, for example, the pressure with which the débris is held against the rocks over which it is moved. In the middle course of a glacier, pressure is normally greater than near its extremity, where active waste is in progress; greater abrasion might, therefore, be expected to occur in its middle course than near its extremity. The firmness with which débris is held in its icy matrix, also influences it action as an abrading tool. It is reasonable to suppose that in a névé region the stones in contact with the rocks beneath, would be held less securely than in the compact ice of a glacier proper. This may be one reason why the upper portions of formerly névé-filled amphitheaters are frequently without smoothed and striated surfaces. Weathering in such situations, however, is more active than in lower regions; which may, perhaps, account sufficiently in many instances for the absence of ice abrasion referred to.

Unconsolidated deposits beneath glaciers.—In the well-known instance of Muir glacier, the ice, at its extremity, rests on unconsolidated gravel. That the gravel well beneath the ice, however, in this and other similar instances, is really unconsolidated may be questioned. It is more reasonable, perhaps, to assume that such subglacial gravel is bound together by ice, and really forms a part of the glacier that rests upon it, but owing to excess of rocky material remains stagnant and allows the less highly débris-charged ice above to flow over it. Although this may be the explanation of the conditions now presented, in the example referred to, it does not explain how the ice first advanced upon the gravel.

The gravel beneath Muir glacier was deposited by streams, in an unconsolidated condition, previous to the advance of the ice upon it, and differs both in character and in the manner of its accumulation from a ground moraine.

A glacier advances, as has been shown by Professor Reid,

owing to the more rapid flow of the surface portion, which carries it over and beyond the ice previously forming the terminus. The more rapid flow of the surface as compared with the basal portion, is, no doubt, due, as commonly stated, to an increase in friction toward the bottom. The basal portion generally, however, contains more englacial débris than the superior portion and for this reason would also be retarded. As fresh ice is carried beyond the extremity of a glacier, it is more and more exposed to conditions which favor melting and thus, if the ice contains débris, tends to increase the percentage of foreign material in the portion that remains unmelted. The ice thus advanced, in its turn, becomes basal and is buried as the ice from above continues to descend.

Even in the case of a glacier composed of clear ice, advancing in the manner just cited, upon an unconsolidated gravel bed, the basement layer would become charged with gravel as a result of the contact and thus caused to stagnate. The ice at the bottom being densely charged with débris might remain stationary until melted and thus protect the gravel below from the erosive action of the ice flowing over it.

Terminal moraines.—In the case of an ice stream which contains englacial débris, the increase in the rate of melting toward its extremity will, as already stated, cause an increase in the percentage of débris in the portion that remains unmelted. As the melting of a glacier is mainly superficial, a concentration of englacial débris is brought about by the débris first becoming superglacial and then falling into crevasses and other openings. As the percentage of débris increases in the wasting extremity, the flow of the ice is retarded, and stagnation finally results. Usually, also, in the case of Alpine glaciers, there is a gradual decrease in volume and also in gradient toward their extremities, which again leads to a decrease in their rate of flow and favors stagnation. The presence of a large percentage of englacial débris in the extremity of a glacier, however, will cause stagnation under conditions that would allow a clear ice-stream to flow on. A dam of débris-charged ice is thus formed which will check the advances of clearer ice from above, and cause it to increase in

thickness and expand. The effects of such a check will vary with conditions.

In the case of a growing glacier, the increasing volume of ice above the dam, would cause it to rise and flow over the obstruction, which would then become subglacial. If the glacier was slowly wasting away, its terminus might remain stationary for a time and increase in thickness and then continue to diminish, leaving its highly débris-charged extremity to slowly waste away and finally leave a terminal moraine. The delicate balancing between conditions which cause a glacier to advance, and those favoring recession, so frequently to be observed, would lead to many variations in the changes induced by the congestion of débris, above considered. This process will be again referred to in connection with the influence of débris on fluctuations in the lengths of ice streams.

It is frequently stated that terminal moraines are formed by the carrying forward of superglacial débris and its projection over the end of a glacier. Ridges of débris may frequently be seen about the extremities of glaciers, which are receiving additions in this manner. Such ridges usually have smooth outer slopes and when the ice withdraws from them, the sides left unsupported, acquire even slopes, also, owing to the sliding down of the material; their crest lines are sharp, but frequently undulating in the direction of their length. Terminal moraines of this character are in reality aprons of débris, analogous to talus slopes at the bases of steep cliffs.

Moraines of another type illustrated by the great terminal which crosses New Jersey, Pennsylvania, etc., have broad, hummocky surfaces, with basins between, and originate from the melting of débris-charged ice. Their irregularities in relief are due to the unequal melting of the ice that held the débris, and the concentrations of the foreign material in depressions after it became superglacial, in the manner now well shown in the broad moraine-covered border of Malaspina glacier. Irregularitie would also result from inequalities in the distribution of the débris while yet englacial.

Two types of lateral moraines, corresponding in the manner

of their accumulation, with the two varieties of terminals just cited, may also be recognized.

The influence of débris on the behavior of glaciers that advance upon a plain and build morainal embankments, like those at the mouth of Bloody Cañon, California, might be traced, but space forbids such an extension of this paper.

Variations of glaciers.—Much attention is now being directed to fluctuations in the lengths of glaciers. As is well known, many Alpine glaciers alternately advance and retreat in the course of a few years, or remain stationary for a term of years and then undergo marked variations. These changes are usually considered to be due directly to variations in meteorological conditions. Glaciers in the same group, however, which, so far as one can judge, are exposed to the same climatic changes, frequently fluctuate differently. One glacier may be advancing, while its neighbor, perhaps draining the same névé field, is retreating. What has been stated above, however, in connection with the stagnation of the extremities of glaciers, when congested with débris, suggests that fluctuations in their lengths may be due to other causes than climatic changes.

Advances and retreats of the end of a glacier may evidently result from (1) variations in the rate at which snow is accumulated on its névé, (2) to changes in its rate of melting, and (3) to fluctuations in its mean rate of flow.

1. Variations in the accumulation of snow on the névé of a glacier may be considered as causing pulsation, or "waves," which would progress throughout its length and on reaching its extremity cause an advance or retreat. How an increase or decrease in the rate of accumulation on a névé would affect a glacier flowing from it, can, at present, only be conjectured. But it is reasonable to suppose that a moderate "wave" produced in this manner would become less and less well defined the greater the extent of the glacier it traversed, and its final effect on the length of the glacier be inappreciable. Marked changes in the volume of a névé would, however, unquestionably affect the glacier flowing from it and cause variations in its length. The opposite changes exhibited in

neighboring glaciers may also be explained in this way. For example, two glaciers subjected to the same climatic influences, but of unequal length, or if of the same length but of different mean velocity, would advance at different times in response to the same impulse, for the reason that the time required for a "wave" to reach their extremities would be different.

The effects of variations in névé regions on the length of the glaciers flowing from them, have recently been discussed by Professor Reid in this JOURNAL[1] and need not be considered further at present.

2. Variation in the rate at which glaciers melt, might be considered as a factor in studying the halts, advances and retreats observed at their extremities; but meteorological observation in Alpine valleys and the behavior of the ice streams entering the same valleys, do not show an intimate connection.

3. The rate of flow of glacier ice is influenced, as already stated, by the percentage of débris mingled with it. The increase in the percentage of débris near the end of a glacier, may as we have seen, cause it to become stagnant and form a dam of débris-charged ice. When this occurs the terminus of the glacier will become stationary. If the current from above is sufficient to cause the ice to rise, and flow over the obstruction, an advance of the terminus will result. When the energy of the glacier is feeble, it may be held in check for a while, perhaps adding to the height of the débris-charged ice that retains it, and then retreat. The withdrawal of a glacier from its stagnated extremity is perhaps a more varied process than an advance beyond it. The extremity of a glacier that has been checked in the manner here considered, will be covered with superglacial débris. The effect of a surface covering on the wasting ice is varied. As is well known, a small amount of débris, especially if dark colored, will promote melting; while a larger amount will shield the ice beneath and assist in its preservation. For this reason, the abundantly débris-covered extremity of a glacier will waste more slowly than the less thoroughly covered portion farther up stream. In the case of a slowly retreating glacier

[1] Vol. III., 1895, pp. 278–288.

this may cause the clear ice above a débris-charged ice-dam to melt away, and form a new terminus which would in turn become congested and undergo a similar process once more.

An explanation is, then, suggested of the varying behavior exhibited by the extremities of glaciers, which is independent of fluctuation of climate. Two glaciers supplied in their névé regions with the same amount of snow, and alike in all respects except in the percentage of débris carried by them, would have the débris concentrated in their extremities at different rates and hence form débris-charged ice-dams at different periods, and consequently be checked and advance or retreat at different times and at different intervals. If in the case of two glaciers the amount of débris carried was the same, but other conditions varied, the fluctuation of their extremities would again vary. So diverse are the conditions controlling the flow of glaciers, that in no two instances could their fluctuations in length, due to the influence of débris, be expected to occur synchronously.[1]

Drumlins.—In the case of a mass of englacial débris, densest at its center and gradually becoming less and less abundant in all directions, it is evident that glacial motion will be least at its center and increase in all directions until the normal flow of clear ice under the conditions present will be reached. If the central portion of such a mass is sufficiently charged with débris, glacial flow will there cease and the stagnant portion be carried along, for a time at least, as englacial bowlders are carried. If such a stagnant nucleus should be situated at the base of a glacier, however, it would retain its position and the clearer ice above and on either side would flow past it. The "plucking" of débris from such a stagnant mass might lead to its removal, but if the advancing ice contained rock fragments, these on coming

[1] The considerations offered above, lead to the suggestion that a series of terminal moraines in a formerly glaciated valley, or a similar succession of ridges left by a continental glacier, are not necessarily evidence of repeated climatic oscillations, but may have been formed during a uniform and continuous meteorological change favorable to glacial recession. That is, a débris-charged glacier may retreat for a time, then halt, and again retreat, owing to its terminus becoming congested with foreign material, in response to a climatic change which would cause a glacier composed of clear ice, to recede continuously and without halts.

in contact with the débris-charged ice, would be retained, and thus add to the accumulation. The stagnant mass would be under pressure, and both by the addition of material and the removal or plucking away of material, would be given a shape which would present least resistance to the ice flowing past it, and its longer axis would be parallel with the direction of ice movement. That is, it would have the form characteristic of *drumlins*.

As already stated, when the ice at the base of a glacier is generally charged with débris, it may form a stagnant layer over which the clearer ice above will flow. On final melting, the débris in such a layer would form a ground moraine. If inequalities existed in the bottom over which the glacier moves, or the supply of englacial débris is not uniform, stagnant débris-charged ice may be concentrated at one locality and erosion occur at the same time at an adjacent locality. The same thread of the ice current may deposit at one time and erode at another time and *vice versa*, according as it loses or gains in percentage of contained débris or its energy is varied by other causes. When the supply of débris carried by an individual portion of a glacier is long continued, elongated mounds and even lengthy ridges may be formed. All phases presented by drumlins from those accumulated about boss of rock, to oval mounds, elongated hills and long narrow ridges, may apparently be accounted for by the behavior of débris-charged ice and variations in the volume or constancy of the supply of englacial material. There seems no good reason why we might not have drumlins formed of gravel, sand or loess, as well as of till.

While the explanations suggested in this paper may not all hold when more thoroughly considered, and when tested by observation and experiment, yet I feel confident that the principle on which they are based is valid and will be found important both in discussing theories of glacial motion, and in explaining the mode of origin of many glacial deposits.

ISRAEL C. RUSSELL.

GLACIAL STUDIES IN GREENLAND. VIII.

The Krakokta Glacier.—Of the glaciers that descend northerly from Redcliff Peninsula, the Krakokta is the most important and instructive. It takes its rise in the north central portion of the nevè field of the plateau and descends a relatively long valley by a series of moderate cascades, rather than the single one which characterizes the descent of the glaciers previously described. The last of these cascades lies opposite the head of Bowdoin Bay, at the point where the plateau gives place to the lowland that connects it with the mainland. On descending this, the glacier spreads out upon the lowland into a broad, flaring foot, the right-hand portion of which immediately overlooks the head of the bay, while the central portion is forced into direct contact and conflict with the Tuktoo glacier which descends into the same lowland from the main ice-cap on the north, and the left-hand side spreads out upon the flats toward the head of McCormick Bay. In descending this lower cascade the ice is much broken and presents a very ragged aspect, but I did not observe that it differs in any notable way from the analogous ice cascades of southern glaciers.

The collision of the Krakokta and the Tuktoo glaciers, gives rise to a very interesting joint moraine. The Krakokta glacier coming from the south carries chiefly red sandstone in its basal layers. The Tuktoo glacier coming from the north carries chiefly gray crystalline rock. This contrasted material has been heaped up into a single sharp ridge, the south side of which is red from the dominance of the sandstone, while the north side is gray from the dominance of the crystalline rock. The contribution of each glacier is thus strikingly displayed. The dividing line between these contributions runs essentially along the crest of the moraine. Each glacier seems to have done an equable share of the work of forming the moraine. It should be said, however, that I only examined the eastern part of

FIG. 52.—Seracs of the lower cascade of the Krakokta glacier.

FIG. 53.—View of the lower part of the Krakokta cascade looking northwesterly. The dark line which crosses the figure near the center is a *joint* terminal moraine, formed by the contact of the Krakokta and Tuktoo glaciers, moving from opposite directions, the former from the south, the latter from the north. Beyond the moraine near the extremity of Tuktoo glacier, a small nunatak is seen at the right of the figure, around which the ice is depressed. The larger prominence in the center separates the Tuktoo glacier from the Sun glacier. The snow-cap on the heights at the left in the distance is the edge of the ice-cap of Prudhoe Land, and is continuous with the main ice-cap, which lies to the right.

the moraine and this remark may not apply to the western portion where the moraine seemed, from a distance, more deployed and complex. In the portion examined, the glaciers still press against the base of the moraine, but not forcibly. There is a slight valley between the moraine and the ice on either side, though this is not of such depth or steepness as to offer any serious difficulty in passing from glacier to moraine, or moraine to glacier on either hand. The moraine rises but little above the ice on either side, as will be seen by reference to Fig. 54, which is a view of the east end at the point where the glaciers are separated by the Sentinel nunatak.

The surface of the ice adjacent to the moraine is almost wholly free from débris. That which is contributed to the formation of the moraine is borne by the basal layers of the ice on either hand. In the vicinity of the moraine the layers of the ice are curved upwards. This upward curvature of the strata is not, however, confined to the edge of the ice in contact with the moraine, nor indeed to the immediate border of the glacier. In crossing the wide expanse of the foot of the Krakokta glacier, it was observed that the blue layers — which best indicate the stratification of the ice where débris is absent — were continually coming to the surface by an upward curvature which increased as the surface was approached. This gave a beautiful structural expression to the surface of the ice, the layers being delineated in long, graceful, curving lines, concentric with the border of the glacier. It seemed very manifest that, at least in this glacier, the blue and white bands, which appear as stratification in the vertical faces, assume the form of highly inclined folia on the glacier's surface, closely analogous, if not identical, with the much discussed "ribbon structure" of Alpine glaciers.

The eastern border of the foot of Krakokta glacier, between the point of junction with the Tuktoo glacier and the ice cascade previously mentioned, is unusually interesting from the varied relationships which it sustains to the terminal deposits. For some distance southeast from the point of contact with the Tuktoo glacier it lies opposite the Sentinel nunatak. For the rest of the distance around to the cascade it lies opposite the

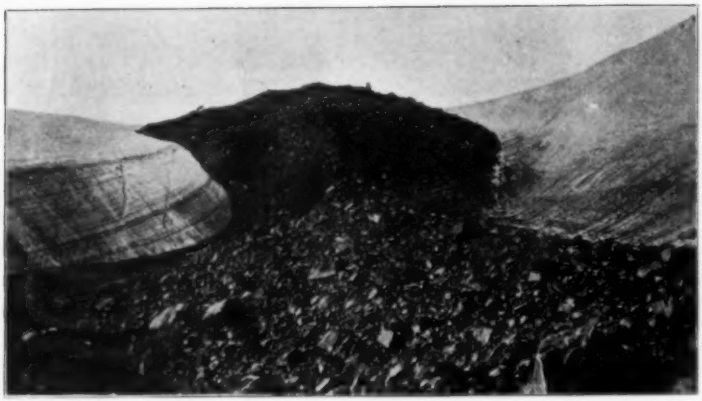


FIG. 54.—A *joint* terminal moraine formed by the direct opposition of the Tuktoo glacier, which is seen on the right, and the Krakokta glacier, which is seen on the left. The point of view is opposite the east end of the joint moraine near the Sentinel nunatak looking westerly. The photograph shows the stratification of the ice and in some measure the upward curving of the layers near the moraine.

FIG. 55.—View of the northeastern border of the Krakokta glacier seen from a point near its junction with the Tuktoo glacier, looking southeasterly. A terminal moraine formed by the glacier occupies the right half of the foreground. On the left appears the lower part of the talus slope of the Sentinel nunatak. At its base and between it and the moraine is a stream which drains this part of the Krakokta and a part of the Tuktoo glacier. In the central portion of the figure the glacier is seen to have crept out upon its terminal moraine and to be overhanging the valley through which the drainage escapes to the Krakokta Cove at the head of Bowdoin Bay, which lies just beyond the center of the figure. The heights at the right are the northeastern promontory of the Redcliff peninsula.

northwestern limb of Bowdoin Bay, known as Krakokta Cove. In the portion opposite the Sentinel nunatak the ice does not push against the promontory, although it would do so if its border described a natural curve. The ice holds aloof, so to speak, and leaves space for a drainage stream and a terminal moraine. This is perhaps due to heat reflected from the nunatak.

This relationship may be seen in Fig. 55, as well as the much more interesting relationship of the glacier to its moraine. In the foreground, it will be observed that a fine terminal moraine has been formed outside the present border of the ice. In the center of the figure, however, it will be noted that the ice has advanced over this and has taken on a peculiar rounded border, much as though it were rolling forward over the moraine, while the bottom of the ice was being held back by friction. And this is not altogether an illusion, although the process scarcely amounts to rolling.

Quite in contrast with this aggressive disposition and this convex front is the concave front and retiring disposition shown only a few score rods back along the same border, where it falls behind the moraine shown in the foreground of Fig. 55. If we climb over this moraine and descend to the ice, we have the view shown in Fig. 56. It will be observed that the ice here has neither the tumid, advancing brow which it takes on a little farther east, nor the vertical wall which is common to the region, but a sloping face with a concave tendency. At the same time, the stratification assumes almost the regularity and symmetry of a musical staff. The amount of débris borne between the ice layers, as will be seen, is not very large, and seems to ill accord with the massiveness and coarseness of the moraine. It is to be noted, however, that the ice extends beneath the moraine, and that the latter may, therefore, owe its material largely to ice layers now concealed. The amount of buried ice could not be determined, but apparently its mass was large and constituted a considerable factor in the make-up of the moraine. On the melting of this the irregularities of the moraine will doubtless be accentuated.

Along this sloping border of the ice a suggestive view

FIG. 56.—View of the edge of the Krakokta glacier within the moraine seen in Fig. 55, showing a sloping, slightly concave border, and remarkably parallel stratification.

FIG. 57.—Near view of a portion of the sloping border of the Krakokta glacier, showing the strong individuality of the layers, and *perhaps* their individuality of motion.

(Fig. 57) was taken, which seems to bear upon the interpretation of the projection of the layers of the ice over each other alluded to in the descriptions of the two preceding glaciers. Attention was there called to the hypothesis that this projection was due to the superior melting of the débris-bearing layer. It seemed that there was no doubt as to the correctness of this interpretation in many cases, perhaps in most cases, but there appeared to be other cases in which the explanation was less satisfactory, if not untenable. In the photograph here taken, reproduced in Fig. 57, it will be seen that the under edge of several of the layers is notably cleaner and fresher than the outer edges which are roughened and débris-covered. The aspect is strikingly like that of layers which have moved over each other in such a way as to expose fresh under-edges. Unfortunately this particular feature did not attract my attention when on the ground, and I am only able to submit the evidence of the photograph for what it is worth. The strong individuality of the beds is at least worthy of note.

A short distance beyond the point where the ice is seen to be creeping over its moraine (Fig. 55), the border again retires within the moraine, and this continues perhaps half a mile in the course of which the moraine deploys into a fine series of conjoined morainic ridges, closely pressed together, but yet presenting distinct and sharp crests. These reach a height, according to a single aneroid measurement, of about 275 feet above the Cove and attain a breadth and massiveness which entitles them to rank among notable moraines. Here, however, as before, it was observed that ice was buried beneath the débris, and it was impossible to determine how far the massiveness of the moraine was rendered illusive by the included ice. There seemed ground, however, to believe that the melting of the concealed ice will cause a notable shrinkage of the moraine, and in doing this will greatly increase the irregularity of its surface. It will then doubtless become a typical "humpty-dumpty" moraine.

Following this stout moraine southward, the glacier is found again to be creeping out upon it. But here the ice not only

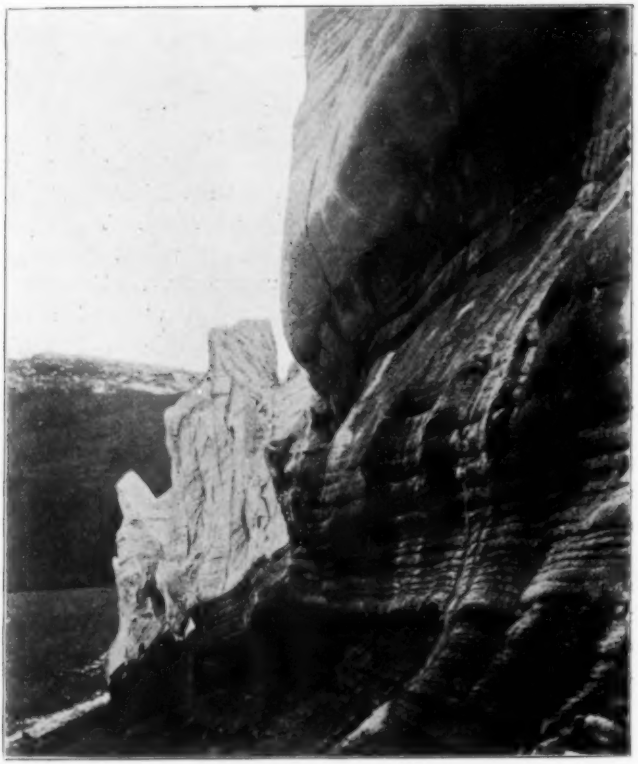


FIG. 58.—View of the east edge of the foot of Krakokta glacier, as seen from the moraine at the point where it is vanishing beneath the glacier.

creeps out upon it, but pushes entirely across it and down its outer slope until the glacier's foot rests essentially on the flat ground at the head of the bay. It has apparently made a descent on the outer slope of the moraine of more than 200 feet. Some allowance, of course, is to be made for the burial of the base of the glacier, and for illusions that may spring from the resting of the moraine on the edge of the ice. There is no room, however, to doubt that the moraine is really very massive, for the glacier is much crevassed where it crosses it, as shown partially in Fig. 58, and again in Fig. 59. Not only is it crevassed on the border, but the course of the overridden moraine may be traced along the surface of the glacier by the line of crevassing to which it gives rise. This crevassing was sufficiently pronounced to occasion some difficulty in crossing the upper surface of the glacier at the most remote point to which the ruptured tract could be traced, *i. e.* at the point where it merged into the crevassed field occasioned by the descent of the glacier from the upland, previously noted.

Fig. 58 shows the border of the Krakokta glacier at the point where the terminal moraine is disappearing beneath it. The ice wall on the right, which here resumes the vertical habit of the region, is notable for the distinctness and regularity of its stratification. It will also be noticed that here, as elsewhere, the beds at the base of the ice are inclined upwards. At the foot of the picture we catch a glimpse of the vanishing border of the moraine. In the center the crevassed border of the ice is seen very imperfectly—because of the oblique line of vision—as it descends the outer slope of the moraine. The border is riven into pinnacled masses and these are leaning and even toppling over as they descend the slope. The purity of the upper portion of the ice is in striking contrast to the dirtiness of the débris-set base. At the left and below there is a delta plain formed by wash brought from under the glacier at the foot of the cataract previously described.

If we now descend to this delta plain and ascend the heights opposite and reverse our line of vision, the general aspect of the upper surface of the glacier where it is creeping over the

FIG. 59.—View of the eastern border of the foot of the Krakokta glacier seen from the heights near the lower ice cascade.

moraine and down its outer slope may be viewed to advantage, as fairly well illustrated in Fig. 59.

We are here looking in a direction opposite to that from which we have approached in the preceding description. The right hand portion of the glacier in the middle foreground is the part which has pushed over the moraine, and crept down to the delta plain which occupies the low land at the right of the figure between the glacier and Krakokta Cove. The ice-strewn surface of the latter appears in the center of the picture. Near the middle of the picture the jagged edge of the glacier indicates the crevassing produced by its passage over the moraine. The line of crevassing across the upper surface of the glacier is not brought out in the picture. Beyond this jagged edge the moraine may be seen imperfectly as a dark mass. The promontory in the background is the Sentinel nunatak. The Bowdoin glacier lies at the right of this, debouching into the head of Bowdoin Bay. In the distance, at the right, are seen dimly two of the lobes of the main ice-cap. The latter covers the heights between these, but is not differentiated from the sky, in the photograph.

From the relations of the Krakokta glacier to its moraines it is obvious that, in recent years, it has been stationary or retreating at some points and advancing at others. The gains and loses very nearly balance each other. From the massiveness of the moraines and the manifest slowness of the glacial action it is probably safe to infer that the border has occupied nearly its present lines for a considerable period.

T. C. CHAMBERLIN.

EDITORIAL.

THE North Greenland Expedition of 1895, the primary object of which was to bring back Lieutenant Peary and his companions to the United States, left St. Johns on the 11th of July. The start had been planned for the first of the month, and the unfortunate delay made it necessary to omit the considerable stops which were to have been made in South Greenland for the purpose of studying the glaciers of that region. Brief stops were, however, made at Holstensborg, Godhavn, Jacobshavn and Atanikerdluk. Melville Bay was passed without notable incident, the water being nearly free from ice. Cape York was reached on the 30th of July, and Whale Sound on the 31st Here for the first time, no more than twenty-five or thirty miles from our goal, ice was encountered in such quantity as to stay our progress.

Mr. Peary's headquarters were reached on the 3d of August, where the main facts concerning his year's work were learned. The provisions which had been cached on the ice-cap for the trip of 1894, not being used that year, were relied upon for the journey of the succeeding season. In September 1894, after the departure of the Falcon, an attempt was made to visit the nearer caches. One of the objects of the visit was to get the provisions out from beneath the season's snow, so as to make them more accessible when the journey of the following spring should be begun. Although the same caches had been visited in the preceding July, and the provisions then raised to the surface of the snow, it was found in September that the snowfall of the summer had been so heavy that neither of the two most important caches could be found, even the signals having been completely buried. After this discovery little hope was entertained that search for the caches would be more successful in the following spring. As the buried caches contained the pemmican, which was to

have been the chief article of food, and the alcohol, which was to have served as fuel, Mr. Peary was obliged to face the prospective loss of both. With this unpleasant outlook, the winter was passed.

Instead of giving up the proposed journey across the ice-cap, Mr. Peary made such provision for the trip as was possible, and on the first of April, accompanied by Lee and Henson, started for Independence Bay. As had been expected, the important caches were not found. In spite of this, the crossing of the ice-cap was successfully accomplished, the distal edge being reached on the 13th of May. The rest of the month was spent on the land about the bay. From lack of provisions a longer stay was impracticable, and the return journey across the ice was begun on the 1st of June and ended on the 25th.

The enterprise and courage with which Mr. Peary conceived and attempted to execute his plans would seem to have entitled him to more consideration at the hands of the powers that be. On two successive years his well matured plans have been thwarted by circumstances over which he had no control, and upon which he could in no way count.

While adverse circumstances have made it impossible for him to carry out in full his plans with reference to the north coast of Greenland, he has nevertheless accomplished much during his Arctic residence. He has twice (in 1892 and 1895) crossed the ice-cap from Inglefield Gulf to Independence Bay, and has gathered information concerning the inland ice, and the ice-free territory beyond, which possesses unique value. Further, he has mapped a considerable stretch of the coast west of Greenland, in the vicinity of his headquarters. The full value of this work will first appear when the map is published, but a few general statements will indicate something of its scope. It covers the coast from Cape Alexander (lat. 78° 10′) on the north, to Cape York (lat. 75° 55′) on the south. Within this latitude, the range in longitude is nearly 8°. The coast is very irregular, as may be inferred from the fact that its actual length, including the islands near the mainland, is about 1000 miles. A comparison of Mr. Peary's MS. map with the earlier charts of the

same region reveals the extent and importance of the changes, which are so great as to make it apparent that the new map is really such, and not merely a corrected copy of the old. The modifications are so extensive that, were it not for the names, the new map and the last edition of the chart of the same region, issued by the Hydrographic Office, would hardly be taken to represent the same coast. In some places the general trend of the coast is altered many degrees. Many bays are mapped which have not hitherto found representation, and many indentations of the coast which have heretofore appeared on the charts, have been changed in position and size. Eleven islands which do not appear on the published charts referred to have been accurately located, and the position, shape and size of those heretofore represented have been corrected. A large number of glaciers, probably as many as 100, have been located with approximate accuracy, within the region where but ten were represented on the published chart referred to, and even these were in some cases in false positions and greatly exaggerated in size. Astrup's map of Melville Bay, already published, should be mentioned in this connection, since it was prepared while its author was a member of Mr. Peary's corps. Geographers will not fail to appreciate the magnitude and the importance of this cartographic work.

In addition to the map, Mr. Peary has kept a series of meteorological records, probably the most accurate and elaborate which have ever been secured in so high a latitude. Besides the more formal records, he has been observant of the behavior of winds about the ice-sheet, and in this way has come into possession of facts which are not without significance in connection with the problems of glaciology. He has made careful measurements of the rate of motion of one of the most active glaciers of the region, and has carried them through a sufficiently long period of time to give them especial value. He has brought back two large and choice meteorites from the coast east of Cape York, the study of which will possess much popular as well as scientific interest.

In quite another line important studies have been prosecuted

to a successful issue. During his three years and a half of Arctic residence—adding the time of the earlier visit to that of the later—Mr. Peary has made a study of the Eskimos of North Greenland. During this time he has personally come into contact with almost every man, woman and child on the west coast north of the Danish possessions. He has lived among them in such a way as to get from them data which no temporary visitor could secure, and which no one, not understanding their language and not commanding their confidence, could hope to gain. As a result, he is in possession of much fuller knowledge of these people than any one else has ever been. The results of his study, when published, will be an important contribution to ethnology.

Indirectly, the expeditions which Mr. Peary has caused to be made into northern waters have not been without results. Five successive voyages, without accident, have shown that Arctic navigation, under proper management, is not so dangerous as has been supposed. Through those who have accompanied these expeditions much information has been secured touching the natural history, the geography and the geology of the regions visited. Some of these data have been published, while others have not yet appeared, but they must, nevertheless, be taken into account in enumerating the results of the several expeditions for which Mr. Peary has been responsible. It will be readily seen that the returns are, in the aggregate, very considerable, and that, although the object which was first in mind when the last expedition was planned has not been fully attained, the results which have been achieved cannot be looked upon as incommensurate with the outlay. R. D. S.

So far as concerns the geographical and geological work of the expedition which has just returned, it may be said that the coast of Greenland, from about 64° 25′ to 78° 45′, was seen at sufficiently close range to allow of a general study of its geographical features. This study was interrupted more or less by the fog which hung about the coast with exasperating persistency. Nearly the whole of the coast of Disco was seen under advantageous conditions. At Holstensborg, Godhavn, Jakobshavn

and Atanikerdluk, opportunity was afforded for a cursory study of local geological features. At the last named place fossil leaves were collected in considerable numbers.

The month of August was spent between the parallels of 75° 50′ and 78° 45′, the latter being the most northerly latitude reached. Between these parallels nearly every mile of the Greenland coast was seen at close range, and a considerable number of glaciers were studied in detail. The American coast also was seen at intervals between the parallels of 78° 45′ and 71° 30′. While few stops were made on this side, the land was within sufficiently close view to make the recognition of its general features possible. Its contrast with the coast of Greenland in corresponding latitudes was most instructive.

In connection with glacial studies, some interesting facts were gathered in connection with glacier motion and glacier work. Some determinations were also made concerning the former extension of ice in relatively recent geological time, and concerning recent changes of level.

In other lines the expedition was successful. Of special interest are the two meteorites which were secured at a point a few miles off Cape York. The Falcon attempted to reach them in 1894, but was unable to do so on account of ice. The larger of the stones has a weight of something like three tons, while the weight of the smaller probably does not exceed one thousand pounds. Both appear to be wholly metallic. R. D. S.

What appears to be authentic information concerning the Jackson-Harmsworth polar expedition has been recently published by the London *Times*, from which paper the following facts are gleaned. The Windward reached inhabited lands about the middle of September in the course of her homeward journey. She has experienced an exceptionally severe winter in the Arctic regions, and the difficulties arising from extreme cold have been aggravated by the fact that she encountered a great amount of ice through which she was obliged to force her way. The information furnished by the dispatches indicates that on the 7th of September, 1894, the expedition arrived on the coast of Franz-

Josef Land, and the total equipment was safely landed. A few days later ice closed in about the Windward in such wise that she was unable to escape from the coast, and remained there through the winter. From this point the party began its northward journey on the 10th of March. By May they had established a depot of provisions as far north as latitude 81° 20′, which was about 100 miles beyond the point where the winter was spent. The outlook for the future work of the expedition is good, and it is believed that when the ship goes out again next year to meet the party, it will bring the welcome news of successful exploration in the almost unknown area. The party is reported to be in good health and full of courage with reference to their future work. R. D. S.

PUBLICATIONS.

Notes on some Eruptive Rocks from Gallatin, Jefferson and Madison Counties, Montana. By GEORGE P. MERRILL, Proc. U. S. National Museum, Vol. XVII., pp. 637–673, Washington, 1895.

In these notes Professor Merrill has described some of the more interesting rocks of those collected by Dr. A. C. Peale and himself in the parts of Montana named in the title. The notes are arranged according to the geographical occurrence of the rocks rather than upon a petrographical basis, which latter would have been more convenient for reference. The rocks are in part extrusive, including basalt, several kinds of andesite and rhyolite; and in part intrusive, embracing a wide range, from syenite and diorite to peridotite and pyroxenite, and including a number of porphyritic rocks some of which are lamprophyres.

The andesites are normal for this region and are only briefly described. In the case of a hypersthene-andesite a complete chemical analysis is published. The rhyolites and basalts are normal, except for a quartz-bearing basalt like those found in other parts of western America. Diabase and diorite of various kinds are briefly mentioned. Several peridotites are described in considerable detail. They occur in areas of crystalline schists but appear to be of eruptive origin. The rocks are classed as wehrlite, hornblende-picrite, saxonite (harzburgite). Closely related to them in composition and mode of occurrence are certain pyroxenites, one of which is hornblende-hypersthenite, while another is websterite. The value of these descriptions is enhanced by complete chemical analyses, which fortunately have been made from very fresh material.

The special interest of the paper lies in the description of a number of lamprophyric rocks and of closely associated syenitic porphyries; besides several porphyritic rocks described as porphyrite (?), augite-porphyrite, and in one case as basalt (?) These descriptions are full and embrace the chemical composition of the rocks and also of some of the more prominent constituent minerals. One class

carry phenocrysts of olivine and augite, but none of feldspar. The groundmass is extremely fine grained and is in part obscured by alteration products. It is basaltic to a great extent, but contains orthoclase in microscopic crystals, or else shows upon analysis a relatively high content of alkalies. Mica is also a prominent constituent in some instances. Professor Merrill's remark upon the mutual interference of the phenocrysts of augite and olivine, namely, that it "can be accounted for only on the supposition that neither mineral is a direct secretion from the magma, but that they are residuals of an earlier crystallization in which consolidation had proceeded so far that free growth was no longer possible," appears to the reviewer to be greatly in error. One need only mention the pegmatitic intergrowth of phenocrysts of quartz and orthoclase in certain obsidians and pumices, and the mutual penetration of pyroxene and hornblende in phenocrysts in some glassy andesites. Chemically the rocks belong with lamprophyres, and resemble some rocks found in the Absaraka Range, in the Yellowstone National Park.

The porphyrite-like rocks carry phenocrysts of plagioclase in addition to those of augite and olivine, and have a groundmass in which orthoclase occurs in connection with plagioclase. The syenitic rocks are closely associated with the lamprophyric ones: and in one case the chemical composition of the syenite is very similar to that of the sodalite-syenite of Square Butte, Highwood Mountains, Montana, as pointed out by Professor Merrill. The reviewer hopes to be able to present shortly in this JOURNAL an account of the closely related series of rocks occurring in the neighboring region of the Yellowstone Park, to which Professor Merrill has referred in his article.

J. P. I.

Highwood Mountains of Montana. By WALTER H. WEED and LOUIS V. PIRSSON. Bull. Geol. Soc. Am., Vol. 6, pp. 389–422. Pls. 24–26. Rochester, April 1895.

The situation and topographic features of the Highwood Mountains are briefly described, and the geologic structure of the district is pointed out. The mountains consist of the denuded remains of volcanoes whose rocks show extreme differentiation of a highly alkaline magma. There are several volcanic cores now filled with massive granular rock. These are surrounded by tuffs and volcanic breccias with lava-flows and a great number of radiating dikes.

The main mass of mountains consists of basaltic breccias resting upon Cretaceous sediments, and also upon acidic tuffs and breccias, which are earlier than the basaltic rocks. The radial disposition of the dikes is one of the most marked characteristics of the geologic structure, and is well shown on the map. The soft Cretaceous strata consist of sandstones and clayey shales belonging to at least two groups; the lower referred to the Kootenia, the upper possibly representing a southward development of the Belly River formation. The strata are nearly horizontal or but slightly inclined away from the mountains. In the vicinity of the volcanic cores the sedimentary rocks are metamorphosed into dense hornstones and quartzites, quite like the baked Algonkian slates or Cambrian shales of Castle Mountain, or the metamorphosed Livingston beds about the volcanic core in the Crazy Mountains.

The chief interest of the region is in the character and occurrence of the igneous rocks, and in the differentiations of magmatic material that has taken place at each of the volcanic cores. The South and Highwood cores consist of syenite; from them radiate dikes of basaltic rocks, in part leucite or analcite-basalt; in part dark rocks with large plates of black biotite. Complementary rocks in the form of porphyries also occur. About the Highwood core the first rocks erupted were acidic tuffs and breccias, intermingled with flows of felsite and possibly phonolite. These were succeeded by breccias and lavas of basaltic material similar to the dikes just mentioned. The east core is of syenite, partly surrounded by basaltic lavas and breccias.

The Shonkin core is the largest in the district and consists of granular rock, in one place breaking up through basaltic breccia. The Arnoux core is of similar granular rock, which breaks through acidic tuffs and basaltic lavas.

Palisade Butte is a volcanic core of coarsely crystallized basic rock like that in Square Butte, and called shonkinite. It is a columnar mass topped by syenite which appears to have been extruded through the shonkinite. The rocks mentioned in connection with these cores have not yet been described in detail but are said to be of novel types and of great interest petrologically. At Square Butte, an eastern outlying mountain of this group, the character of the igneous rocks is such that they have been specially described. The butte is a flat-topped mass rising 1700 feet above its base. The igneous rocks form a laccolite once covered by Cretaceous strata, now almost completely bared of its covering. The topographic character of the mountain and

the forms of erosion assumed by the rocks are shown in numerous illustrations.

The lower half of the rocky slopes of the mountain consists of dark-colored rock eroded into towers and spires, which are strongly contrasted with the light-colored upper half of the mountain, where the rock is in large masses and cliffs. The white rock is sodalite-syenite, already described by Lindgren, the petrographical characters of which are briefly reviewed. The dark rock is a new type of rock consisting of much augite and less orthoclase, besides olivine, biotite, albite, anorthoclase and accessory nephelite, sodalite and other minerals. The chemical composition of the rock, and that of the pyroxene are given, and the mineralogical features of the rock are fully described. The name shonkinite is proposed for the new rock. The two rocks of the laccolite form one mass, erupted at one time; the marked differences between them being the result of differentiation subsequent to their intrusion within the sedimentary rocks. The process of differentiation is discussed at length, and the opinion is expressed that no one simple process will explain all cases, but that a variety of factors must be taken into account, any one or all of which may operate to produce a given phenomenon. J. P. I.

The Laccolitic Mountain Groups of Colorado, Utah and Arizona. By Whitman Cross. Fourteenth Annual Report of the Director U. S. Geological Survey, for 1892–3. Washington, 1895. 84 pp., 10 Plates, 19 Figures.

Having become familiar with numerous instances of laccolitic intrusions in Colorado, and having noted how much doubt concerning their true nature existed in the minds of some foreign geologists, Mr. Cross has undertaken to present the facts already known of such bodies of igneous rocks, so far as concerns their occurrence in regions explored by himself and in the neighboring regions of Utah and Arizona. And in so doing he has endeavored to establish more clearly the various phases of laccolitic intrusions within sedimentary strata, and to describe the petrographical character of the igneous rocks that constitute such intrusive bodies. The paper first reviews in considerable detail the facts established by Gilbert regarding the laccolites of the Henry Mountains, and the theory he advanced in explanation of them. It also reviews the characters of the rocks from a study of the specimens collected by Gilbert and originally described by Dutton. According

to modern nomenclature the rocks would now be called porphyrites, and the recent study with better thin sections confirms the conclusions of Dutton that the specimens collected from laccolites and dikes indicate no differences of composition or structure corresponding either to geographical or geological distribution, or to the size or form of the intruded masses.

The West Elk Mountains are described and the numerous instances of laccolitic mountain masses noted. Some of these masses were described by Holmes and Peale in reports of the Hayden Survey for 1873 and 1874. They have been more recently studied by Cross. The individual mountain masses of this group consist of homogeneous igneous rock, which in a number of cases is clearly shown to be intrusive within sedimentary strata, and is accompanied by sheets and dikes of the same eruptive rock. The character of the rock is very nearly the same as that of the Henry Mountain laccolites. The microstructures of the rocks of the different masses are practically the same, indicating that even the highest bodies solidified under a great load. The strata in which they have been intruded is Cretaceous, and the age of the intrusion is Tertiary.

The isolated mountain groups of San Miguel, La Plata, Carriso, El Late, Abajo and La Sal, which were studied by Holmes and Peale, are reviewed and their structure noted as that of laccolitic intrusions within nearly horizontal strata. The rocks in all cases are of the same general type of porphyrites. Intrusions within more or less disturbed strata of older age and also within the crystalline schists, which have been studied by Cross, are described. They occur in the Mosquito Range and the Ten Mile District. Here the igneous bodies form sheets and dikes, the rocks having the same general structural characters as in those previously described, but having a somewhat wider range of composition. Other occurrences of similar intrusions within the ranges of the Rocky Mountains are mentioned. In conclusion Cross points out the fact that while the rocks forming these intrusive bodies show considerable variation in composition, the great majority of them belong to one well marked structural type, that of porphyry; and that this is plainly the result of the similarity of conditions of consolidation upon magmas which are much alike in their controlling elements. He adds that there is every reason to suppose that other eruptive provinces may be characterized by intrusive masses of other rock types. If the magma of another region were very different from that so common in the region described, another structural type might

result from the same conditions of cooling. He points out the fact that the rocks of the plateau groups and those of the mountain area of Colorado differ in the relative abundance of alkalies, those of the latter area being higher in potash. These observations apply to all igneous rocks whether in the form of laccolites or not, and the rocks of the Yellowstone Park, whose analyses are placed in a table for comparison with those of the rocks Cross has described, are not laccolitic, but dike-like intrusions. Since Cross wrote this paper Pirsson and Weed explored the Highwood Mountains and published the description of the laccolite of Square Butte, whose rock is granular syenite and shonkinite, very different in structure and composition from the porphyries described by Cross.

In discussing the mineral composition of the rocks Cross lays stress on the fact that in some cases large orthoclase phenocrysts have clearly been crystallized after other constituents which do not appear as phenocrysts. He finds no evidence that any of these eruptive masses "absorbed" sedimentary masses. There is in fact almost no metamorphism of sedimentary rocks along the contact with these igneous bodies.

Owing to the great range in geological distribution and in size and form of masses of practically identical rocks, Cross concludes that the conditions of cooling or consolidation were almost the same throughout a wide (deep) zone, and that pressure as a function of depth has had very little influence within the limits represented. The rate of cooling must have been essentially the same for all masses, indicating that below a certain depth there is a zone in the earth's crust within which conditions of cooling are practically uniform. The upper and lower limits of this zone are not known, but it would seem as if a depth of several thousand feet must be necessary to secure a temperature so high and a rate of cooling so slow that the chilling effect upon an intruded magma should be no greater than that at a depth of 20,000 feet. We do not find that Cross considers the consequences of magmas having quite different temperatures when they reach the place of laccolitic intrusion, or that he discusses possible differences of temperature of the enclosing rocks due to local causes.

In describing the structure of laccolitic rocks, Cross discusses the terms *porphyritic* and *granular*, and expresses the opinion that they should be limited to purely formal ideas, without regard to the possible origin of the structures, and that they should not be confined to megascopic textures, but should be used for the same kinds of structure whether megascopic or microscopic.

As to the forms of laccolites he does not believe in limiting the term to those intrusive bodies only that occupy a perfectly regular position with regard to stratification planes, but would apply it to any intrusive body where the expansion of the body has taken place from a plane even approximately parallel to the bedding. In horizontal strata the lifting of the load by the intrusive force may be taken as the prime essential. The deviations from the type forms from accidental causes are many. With regard to the origin of laccolites Cross cites a number of facts which demonstrate that the horizon occupied by intrusive magmas are not determined by relative densities of the intruding lavas and of the invaded strata, as suggested by Gilbert, and assuming eruptive energy such as exists in active volcanoes he concludes in the words of James D. Dana that "no other cause could be needed for a flow to the surface in case of an open channel, or for a flow to any level in the strata at which a fissure might terminate; and this is true whether the lava be light or heavy." J. P. I.

Petrology for Students. An introduction to the study of rocks under the miscroscope. By ALFRED HARKER. Published by Macmillan & Co., New York, 1895. Price $2.

As the author states in the preface this text-book is prepared especially for English students, nevertheless it will be found very useful for those beginning the study of petrography in this country, who wish a text-book written in English. No systematic account of the crystallographic and optical properties of minerals has been attempted, and for such information the student is referred to the translation of Professor Rosenbusch's volume on the rock-making minerals. But as an introduction to the study of the rocks themselves a number of useful observations of a general nature are presented upon the characters of minerals in thin section, and especially the latest methods of distinguishing the different varieties of feldspar. In treating so complex a subject as the optical properties of minerals in thin sections in such a condensed manner it is doubtful whether the author can meet the wants of a beginner. It serves, however, as a form of definition of the terms used throughout the book. It would seem that in neglecting the use of those methods of determination based on the optical phenomena observed with converging polarized light the author needlessly weakens the processes of petrographical diagnosis.

In his remarks upon the examination of rock sections the author

shows his appreciation of the broad field of the science, which, as he says, is not merely an attempt to discover the composition of a rock, but to unravel its history as well. His clear understanding of the subject is also shown in his discussion of the classification of rocks, especially those of igneous origin. In the present chaotic condition of the nomenclature of rocks it will be difficult for any one, who does not succeed in reforming the whole system, to classify rocks to his own complete satisfaction or to the satisfaction of anyone else. In his attempt at simplification Mr. Harker has shown his independence to a considerable extent, while following in the main the classification of igneous rock adopted by Rosenbusch, though under a different terminology. Thus massive igneous rocks are subdivided into *plutonic*, *intrusive* and *volcanic*, corresponding closely to *tiefengesteine*, *ganggesteine and vulkanischegesteine*. In many other ways also the author follows the methods and principles of Rosenbusch. Under each of the three great divisions above named the rocks are arranged according to their mineralogical or chemical composition beginning with the most acid. The names used for varieties of rocks within different families are generally those expressing the mineralogical characteristics of the particular variety rather than those of a geographical character, which may already be in common use. But in most cases both names are given. The most noticeable instance of this is in the treatment of the peridotites.

In substituting the term *intrusive* for that of *ganggesteine* and in maintaining an independent grouping for certain varieties of intrusive rocks the author has not improved on the presentation of the case as made by Rosenbusch, and his remarks in introduction of his *intrusive* division are in the nature of an apology. Nor does his use of the term, acid intrusives, in distinction to that of porphyries and porphyrites, appear to be fortunate. Diabases are classed as intrusives. Under *volcanic* rocks no distinction is made between older and younger lavas, which certainly seems to be the only proper method of treatment. In this respect the classification follows the English usage. The fragmental products of volcanic action are described in connection with sedimentary rocks.

The descriptions of the various rocks embrace a general definition in mineralogical and structural terms, followed by an account of the constituent minerals and of the microstructure. Illustrative examples are chosen as far as possible from occurrences in Great Britain. The many references to the writings of British geologists and numerous

others to the works of foreigners add greatly to the usefulness of the book for more advanced students.

The sedimentary rocks are divided into *arenaceous, argillaceous, calcareous* and *pyroclastic* kinds. Under the first division the general terms are defined, and the characters of the derived grains and of the authigenous constituents are discussed separately. In this way the general characteristics of all arenaceous rocks are given rather than the specific character of any one kind of rock.

In the chapter on argillaceous rocks the general definitions are first given, then the characters of the constituent minerals, followed by that of the structure. The description of illustrative occurrences serves to supply the need of some definite picture of different kinds of these rocks. The treatment of calcareous rocks is admirable for so condensed a statement. It deals first with the source and composition of these rocks, then the structure of organic fragments; followed by oolitic structure, the character of the matrix, and of deep-sea calcareous deposits. Finally metasomatic changes are described, and British examples cited. References to the literature of the subject are numerous and valuable. Pyroclastic rocks are briefly treated. Deposits due to chemical or to organic agencies are described in a few short paragraphs.

Under the head of metamorphism the author discusses the general principles of the subject, and then describes the changes produced by thermal metamorphism upon the different kinds of sedimentary rocks, and upon igneous rocks and the crystalline schists. This is followed by an account of the effects of dynamic metamorphism upon the minerals and structures of rocks. Very little space is devoted to the petrographical description of the various kinds of crystalline schists, which are grouped under the heads of crystalline schists, gneiss, granulites and eclogites. The basis of classification is structure.

The book shows careful preparation, and although the reviewer has taken exception to some features of it, he would recommend it to all those beginning the study of petrology. J. P. J.

Boletin de la Comision Geológica de México, No. 1 ; Fauna fossil de la Sierra de Catorce, San Luis Potosi. By ANTONIO DEL CASTILLO and JOSE G. AGUILERA; pp. ix + 53, with twenty-four plates, Mexico, 1895.

The authors state that they propose in this work to confirm the existence of the Jurassic system in Mexico, describing the most

characteristic forms that are common in the more accessible localities.

The introductory pages are devoted to a brief review of previous opinions concerning the stratigraphy and age of the formations in the Catorce district, with quotations from the writings of various geologists and travelers who have either visited the region or studied collections from it. The description of the fauna from the body of the work. in which sixty five species and varieties of invertebrates are described, and nearly all of them are figured. Of these sixty-five forms, five are referred to the Brachiopoda, seventeen to the Lamellibranchiats (including nine Aucellæ), one to the Gastropoda, and forty-two to the Cephalopoda, of which thirty-eight are Ammonites.

The fossils are not all from one horizon, but are distributed through the upper two members of a series, consisting of three groups, as follows, beginning at the base :

1. Metamorphic argillaceous slates, without fossils.

2. Alternating sandstones and marly and argillaceous shales, rich in fossils.

3. Compact gray-ash colored limestones, more or less impregnated with silica, and containing nodules of black flint. The lower part of the group is argillaceous and has a shaly structure. Fossils rare.

The only fossil found in the upper compact limestone is an imperfect ammonite, supposed to be related to *Schloenbachia inflata*, but the calcareous and marly shales at the base of the upper group have yielded five species that are referred to Exogyra, Lucina, Phylloceros and two species of Hoplites. From a comparison of these forms with European species the authors conclude that the upper group probably represents the upper part of the lower Cretaceous, viz., the Aptian and the Albion.

Two divisions are recognized in the middle group (No. 2), of which the upper one, composed of shales and marly sandstones carrying more or less lime, is the principal Aucella bed of the series. The fauna of Aucella recognized are all Russian species, as follows : *Aucella bronni, A. bronni var. lata, A. pallosi,, A. pallosi, var. plicata. A. pallosi var. tenuistriata, A. volgensis, A. fischeriana, A. piriformis and A. terebratuloides.* These species which in Russia characterize various zones in the upper Jurassic and lower Cretaceous, are said to occur together in Mexico in beds, with a total thickness of not more than fifteen feet. Associated with them there are species of Lytoceras, Placenticeras, [?] Pulchellia and Olcostephanus.

The lower division of No. 2 consists of fine-grained sandstones and

argillaceous shales. A single form of Aucella (*A. brouni*) is the only species that it has in common with the overlying division. Its fauna is very rich in Ammonites, especially in the genus Perisphinctes, of which sixteen species are recognized. The other Ammonitic genera represented are Rhacophyllites, Haploceras, Olcostephanus, Hoplites and Aspidoceras.

After discussing the somewhat discordant evidence of the fossils the writers conclude that this lowest fossiliferous bed should be referred to the upper Jurassic, while the upper division of No. 2, in which Aucellæ are so abundant, are believed to be Neocomian.

This important contribution to American Mesozoic palæontology, derives its chief interest from the bearing that it has on the geography of the continent during late Jurassic and early Cretaceous time and on the correlation of the lower Cretaceous fauna of the Pacific coast with that of the Texan region.

It is well known that on the west coast of the United States and British Columbia there is a great thickness of lower Cretaceous strata (Knoxville and Horsetown beds), characterized by an abundant marine fauna. In the Texan region there is another thick series of lower Cretaceous beds (the Comanche series), which is also characterized by a large but totally different marine fauna. The Texan facies of the lower Cretaceous is known to extend into Mexico and over a large part of that country as far west as Arivechi in Sonora. The absence of species common to the two faunas seems to indicate that they lived in different basins without free intercommunication, and this dissimilarity of faunas has prevented exact correlation of the strata.

Catorce, San Luis Potosi, where Castillo and Aguilera obtained the fossils they describe, is near the tropic of Cancer and in longitude 101° East, directly south of the principal Texan area of the Comanche series, and yet the fauna contain none of the characteristic Comanche types, but is related to the Pacific coast faunas. This relationship is especially shown by the abundanee of the genus Aucella which is essentially characteristic of the boreal and Pacific regions, though it is occasionally found outside of those areas. The forms of Aucella, figured from Catorce, though listed under different specific names, can nearly or quite all be duplicated in collections from the Knoxville beds of California. The ammonites also show a number of forms closely related to those of the Knoxville. The lowest fossiliferous zone at Catorce, however, with its numerous species of Perisphinctes, is probably older than the Knoxville. The only suggestion of relationship with the

Comanche series is in the lithological character of the upper limestones, which are described as compact, gray, more or less silicious, limestone with flints, a description that applies equally well to the Caprina limestone, near the middle of the Comanche series. In the almost complete absence of fossils, this limestone cannot now be identified with the Texan formation from the data furnished by the Mexican geologists. Mr. R. T. Hill,[1] however, in an incidental reference to the Catorce region, correlates the so-called "Hippurites" limestone of Mexico, which is probably the same as Castillo and Aguilera's upper limestone, with the Caprina. The same author also refers the lower fossiliferous beds of Catorce to the Trinity division of the Comanche series, but this reference is based on its stratigraphic position rather than either lithological character or faunal contents. From the known distribution of the Comanche series in that region it is at least possible that portions of the Texan and Pacific coast lower Cretaceous faunas may yet be found in direct statigraphic relation with each other in central Mexico.

With the occurrence of the Pacific lower Cretaceous fauna at Catorce, not a great distance from the Gulf of Mexico, and of the Texan or Gulf fauna in Sonora, much nearer to the Pacific, the question as to how the two faunas were kept separate becomes still more difficult. From the data now at hand the most plausible hypothesis seems to be that the sea transgressed the continent, first from one side and then from the other, but never quite crossed the shifting barrier.

T. W. STANTON.

Phylogeny of an Acquired Characteristic. By A. HYATT. Proc. Am. Phil. Soc., Vol. XXXII.

Professor Hyatt's paper "Phylogeny of an Acquired Characteristic," is essentially a contribution to the philosophy of the Neo-Lamarkian school of evolutionists. It is in part a republication in substance of several earlier papers, with the matter now put into a more systematic shape. While primarily biological it possesses great interest for the geologist and perhaps merits a fuller review on that account as it is less likely to fall into his hands.

In the introductory chapter the author lays great stress on the importance of the study of the shells of Mollusca. After speaking of the relation of the shell to the animal, and of the different structures

[1] Am. Jour. Sci., Vol. XLV., 1893, pp. 311, 312, 324.

in the Cephalopod shell, he says: "All their parts, the shell proper, the siphuncle, the septa and the sutures are in correlation with each other and together make an index to the life history of the individual, which is unequaled in some respects among other existing or extinct animals." From the study of a single perfect specimen of a Cephalopod shell can be determined the particular characteristics of the individual at any stage of growth, from the embryonic condition represented by the protoconch, to the retrograde metamorphoses through which it may pass during old age.

The two sub-classes of the class Cephalopoda, Tetrabranchiata and Dibranchiata, with the four orders Nautiloidea, Ammonoidea, Belemnoidea and Sepioidea, are shown to have been differentiated from some common primitive stock, each order being specialized for its own peculiar habitat. The prominence of the depression or sinews in the aperture of the shell is correlative with the prominence of the hyponome or swimming organ of the Cephalopod, and therefore signifies the relative power of the animal as a swimmer. An open aperture is correlative with powerful arms for crawling on the bottom, while forms possessing shells with more or less constricted apertures must have had more or less limited powers as crawlers. In relation to the differentiation of the four orders the author says: "The *efforts* of the Orthoceratite to adapt itself fully to the requirements of a mixed habitat of swimming and crawling gave rise to the Nautiloidea; the *efforts* of the same type to become completely a littoral crawler evolved the Ammonoidea. The successive forms of Belemnoidea arose in the same way. But here the ground-swimming habitat and complete fitness for that was the object. The Sepioidea, on the other hand, represent the higher aims as well as the highest attainments of the Cephalopods in their evolution into surface-swimming and rapacious forms. We cannot seriously imagine these changes to have resulted from intelligent effort; but we can with Lamark and Cope picture them as due to efforts on the part of the animal to take up new quarters in its environment and thus acquire habits and structures suitable to the changed physical requirements of its surroundings and this position is better supported by facts than any other hypothesis."

The relationships of the Nautiloidea and Ammonoidea are next discussed. Many investigators have endeavored, and have failed, to arrange the palæozoic Nautiloidea in a single series, passing progressively from earlier straight forms, through arcuate to the closely coiled forms. Professor Hyatt is led to believe through his investigations,

that instead of a single such series there are several, all originating from a primitive stock and each one passing progressively from the straight form through arcurate, loosely coiled to closely coiled forms.

The order Ammonoidea is in like manner a branch from the primitive stock. The author says: "Thus although both are orders and taxonomically equal, we cannot compare the whole of the Ammonoidea with the whole of the Nautiloidea, but only with a more or less perfect single series of that order." The Ammonoidea have primitive straight radicals, but they are few in number and become extinct in Devonian time, leaving several branches of closely coiled forms, the Goniatitinæ, from which the latter Ammonoids spring.

During the evolution of the Nautiloidea and Ammonoidea, the differentiation takes place most rapidly during the earlier periods of their phylogeny, and their differentiating parts are of more structural importance than later in the life-history. Professor Hyatt formulates these facts in the following general law of evolution: "*Types are evolved more quickly and there are greater structural differences between genetic groups of the same stock while still near the point of origin than appear subsequently. The variations or differences take place quickly in fundamental structural characteristics, and even the embryos may become different when in the earliest period of evolution, but subsequently only more superficial structures become subject to great variations.*"

This law however does not apply to the degenerate forms which appear during the stages of decline of the several genetic series.

In the phylogenetic series, characteristic modifications appear first in the later stages of growth of individuals. These modifications are transmitted to succeeding generations, but are progressively accelerated, appearing in earlier and earlier ontogenetic stages. The law of acceleration is formulated as follows: "*The ancestral characters are brought into contact with new adaptive characteristics, which are being continually introduced into the adult and adolescent stages of ontogeny, and these eventually replace the former which are crowded back to make room for them into earlier stages than those at which they first appeared, and in many cases the latter are reabsorbed and disappear during this process.*"

In the interpretation of the more or less uncoiled degenerate forms of the later phylogenetic stages of the Ammonoidea, the law of acceleration still governs the changes. During Jurassic time degenerate forms are local and the degeneration is exhibited only in the adult stages of the individual. In later Cretaceous time, the majority of the forms show degeneration wherever they occur, and this degeneration sets in

in much earlier ontogenetic stages. The degeneration is exhibited by a reversion to earlier characteristics. The shell becomes straightened, looses its ornamentation and the sutures become more simple, but in all cases it can be shown from a study of the younger ontogenetic stages, that these degenerate forms spring from a closely coiled radical stock. In no case do retrogressive series give rise to secondary radicals which originate new series.

The second chapter is devoted to "Principles of Bioplastology," or the study of the correlation of ontogeny and philogeny. The chapter is made up largely of the explanation of technical terms. Five ontogenetic stages are recognized: (1) embryonic, (2) nepionic, (3) neanic, (4) ephebic, (5) gerontic. Each of these, except the embryonic, is divided into three substages the names of which are formed by the use of the prefixes *ana*, *meta* and *para*, as ananepionic, metanepionic and paranepionic. The corresponding phylogentic stages are designated by the use of the prefix *phylo*, as phylonepionic, etc.

The general adoption of a series of exact terms in investigations of this nature is a necessity, and no one is better fitted to propose these terms than Professor Hyatt. It is desirable that other investigators, as some have already done, should adopt this system of nomenclature.

Chapter III. is devoted to the discussion of the ontogenetic stages of the nautiloidea and ammonoidea. From direct observations Professor Hyatt has determined "*that the substages of development in ontogeny are the bearers of distal ancestral characters in inverse proportion and of proximal ancestral characters in direct proportion to their removal in time and position from the protocouch or last embryonic substage.*"

As a general rule the nepionic stage of nautiloidea draws to a close and the neanic characteristics begin to appear, at or near the completion of the first volution, which growth brings the whorl in contact with the apex or dorsal side of the couch. The ananeanic substage is marked by the first appearance of the impressed zone. This is the name given to the area on the dorsum affected by the contact of the dorsum of the growing whorl with the venter of the already formed whorl of the next inner volution.

This impressed zone can be readily seen to be at first due entirely to a mechanical cause, the resistance of the inner volution to the growing shell of the outer. It is the acquired character the phylogeny of which the author discusses in detail. It can be shown that the impressed zone is invariably consequent upon close coiling, as it is never found in adults of any ancient and normally uncoiled shells.

However as one ascends in the same genetic series to the more specialized nautilian involute shells, this purely acquired character through the action of the law of acceleration or tachygenesis becomes forced back, appearing as a rule in the nepionic stage before the whorls come in contact.

Chapter IV. is devoted to descriptive terms used in the following chapter, in which a large number of genera and species are described, some of which are new, with special reference to the history of the impressed zone.

The last chapter is a summary, and from it may be quoted the following conclusions which seem to be justified by the facts and arguments brought forward:

"1. The impressed zone is primitively a contact furrow, an acquired characteristic of the dorsum of the whorls of nautilian shells having large umbilical perforations, which appear either in the ananeanic or metaneanic substages, and rarely later in their ontogeny. There is abundant positive evidence that in these primitive forms this furrow is purely a mechanical result of the nautilian mode of growth, not appearing in the ontogeny before contact and either partially or entirely disappearing on the free gerontic volution.

"2. The impressed zone does occur independently of contact on the free dorsum of the paranepionic substage as a dorsal furrow in some close-coiled, highly tachygenic, nautilian shells in the Quebec group and in the Devonian.

"3. While there is no positive proof that the dorsal furrow originated through heredity in the paranepionic substages of these nautiloids of pre-Carboniferous age, there is also no satisfactory evidence that it originated in the young of such species as have this character through purely mechanical agencies.

"4. There is no positive evidence that the similar dorsal furrow which also appears at the same age in the young shells of *Coloceras globatum* and perhaps *Coelogasteroceras canaliculatum* among Carboniferous nautiloids can be explained only when it is considered as a transmitted, tachygenetic characteristic.

"5. This fourth conclusion is supported by the presence of a similar dorsal furrow in the paranepionic substage of the young shells of all the nautiloids of the Jura so far as observed.

"6. The fourth and fifth conclusions are rendered still more probable by the presence of the dorsal furrow at an earlier age, the metanepionic substage, in all the nautiloids so far as observed, from the

beginning of the Cretaceous, through the Tertiaries to and including the living species of the genus Nautilus. Its presence on the cystoceran volution in Cretacic shells can be explained only when it is considered as a transmitted, tachygenetic characteristic derived from the ancestral, nautilian shells of the Jura, which have the same characteristic at a later age, *i. e.*, in the paranepionic substage.

"7. The first conclusion is also sustained by the parallel phylogeny of the impressed zone in the ancestral forms of the Ammonoidea, the Nautilinidæ and especially in Mimoceras, the radical genus of this family.

"8. The fourth, fifth and sixth conclusions are also supported by the presence of a contact furrow on the dorsum of the earliest age of the conch in the specialized and highly tachygenic forms of the Goniatitinæ of the Devonian and of all the remaining Ammonoids to the end of the Cretaceous.

"9. These cumulative results favor the theory of tachygenesis and diplogenesis, and are opposed to the Weissmannian hypothesis of the subdivision of the body into two essentially distinct kinds of plasm, the germplasm, which receives and transmits acquired characteristics, and the somatoplasm, which, while it is capable of acquiring modifications, either does not or cannot transmit them to descendants."

S. W.

The Protolenus Fauna. By G. F. MATTHEW. Trans. N. Y. Acad. Sci., Vol. XIV., pp. 101–153. Plates I.–XI.

In a paper entitled *The Protolenus Fauna*, Mr. G. F. Matthew has added an important contribution to our knowledge of the Cambrian faunas of New Brunswick.

The Etcheminian Series, considered as pre-Cambrian by Mr. Matthew, and the overlying St. John Group, present similar stratigraphic features in New Brunswick and Newfoundland. In Newfoundland the Olenellus fauna is found in the same position as observed elsewhere, viz., preceding the Paradoxides fauna, but in New Brunswick the fauna characterized by Olenellus is absent, and the Protolenus fauna takes its place stratigraphically.

The author publishes a list, with notes and descriptions, of seventy-four species and varieties belonging to the Protolenus fauna, twenty-eight of which are new, with two new genera, *Pelagiella*, a new genus of Gasteropoda, and *Micmacca*, a new genus of Trilobites.

The fauna is of extreme interest, being a pre-Paradoxides fauna in which Olenellus is absent. The author says: "Though the Protolenus Fauna holds the place where we might naturally look for Olenellus, the genus is absent, and as so many of the genera associated with it are also absent, *we cannot regard this fauna as the Fauna of Olenellus.*" The author points out that in many respects the fauna is more primitive than the Olenellus fauna. He suggests that the two are contemporaneous, the Protolenus being prelagic, while the Olenellus is a shore fauna. Forms present in the Olenellus fauna differentiated for shore conditions, are absent in this fauna, calcareous corals and sponges are rare, and no Lamellibranch has been observed. Foraminifera belonging to genera which are today deposited most generally in one thousand to two thousand fathoms are abundant in some beds, and the Gasteropoda are of types adapted for deep water.

Heretofore the only pre-Paradoxides fauna described has been that one characterized by Olenellus, and Mr. Matthew's paper is of importance to geologists in pointing out a new facies of the pre-Paradoxides fauna. S. W.

Republication of Descriptions of Fossils from the Hall Collection in the American Museum of Natural History, from the Report of Progress for 1861 of the Geological Survey of Wisconsin, by James Hall, with Illustrations from the Original Type Specimens not hitherto Figured. By R. P. WHITFIELD. Mem. Am. Mus. Nat. Hist., Vol. I., Part II., August 1895.

The republication, with illustrations of the type specimens, of descriptions of fossils which were originally published without figures, is a most commendable undertaking. It is a work of this kind that Professor Whitfield has done.

In the paper descriptions of forty-three species are republished, which are distributed among the fellowing genera: *Buthograptus* (1 sp.), *Callithamnopsis* (1 sp.), *Receptaculites* (5 sp.), *Graptolithus* (1 sp.), *Dictyonema* (1 sp.), *Melocrinus* (1 sp.), *Tellinomya* (4 sp.), *Cypricardites* (3 sp.), *Modiolopsis* (2 sp.), *Ambonychia* (4 sp.), *Pleurotomaria* (3 sp), *Maclurea* (1 sp.), *Ecculiomphalus* (1 sp.), *Lituites* (2 sp.), *Cyrtoceras* (4 sp.), *Oncoceras* (5 sp.), *Orthoceras* (2 sp.), *Gonioceras* (1 sp.), *Illaenus* (1 sp.).

Thirty-three of the enumerated species are from the Trenton horizon, four from the Hudson River, three from the Galena Limestone two

from the Niagara, and one, found in the drift, is supposed to be from the Devonian.

The paper is a real contribution to our knowledge of the faunas of Wisconsin and the Northwest.

S. W.

The Mineral Industry. Its Statistics, Technology and Trade in the United States and Other Countries to the end of 1894. Vol. III., pp. 770 + xxviii + 111 (adv.). The Scientific Publishing Co., New York and London, 1895.

The third volume of *The Mineral Industry* is a worthy successor to the two preceding volumes. The general form and make-up is the same as volume two, yet there are several new subjects and new contributors while some of the former ones do not appear. Each volume of this publication is complete in itself and at the same time a supplement to the preceding volumes and in no sense a duplication of them.

As the name indicates, it is not simply a compilation of statistics, but contains up-to-date scientific articles on the different subjects, written by able specialists. They are all treated, for the most part, from the standpoint of the tradesman. The volumes form a valuable text-book in economic geology, serviceable alike to teacher, student and tradesman. Besides the figures of production there are given the localities, the markets, their geologic relations, and the most improved methods of mining and manufacturing.

The following subjects are treated in the present volume: Abrasives Aluminum, Alum, Antimony, Asbestos, Asphaltum, Barytes, Bauxite, Borax, Bromine Cement, The Chemical Industry, Chrome Ore, Clay, Coal, Copper, Cryolite, Fertilizers, Fluor spar, Gold and Silver, Graphite, Gypsum, Iron and Steel, Lead, Magnesite, Manganese, Mica Mineral Paints, Monazite, Nickel, Petroleum, Pyrites, Precious Stones, Quicksilver, Rare Elements, Salt, Slate, Stone, Sulphur, Tin and Zinc.

The condition of the mineral industry in the different foreign countries is given in separate chapters. There are also articles on Mining Stocks, Electrical Transmission of Power in Mining, Progress in Ore Dressing, Electro Plating, Metallic Oxides, Mining Law and Mineral Development.

As far as possible everything is arranged alphabetically, with numerous valuable tables and summaries, and a complete index both to the

text and to the advertisements, all of which greatly increase its value as a reference book.

The aim of the editor is shown in the following extract from the preface:

> The intention in preparing this work has been to collect and put in convenient form all the reliable statistics of the world; to collect more promptly and more accurately than had hitherto been done the mineral statistics of the United States; and to photograph, as it were, the condition of the industry from year to year, bringing out into boldest relief that information which has the greatest practical value in the development of the industry and which is not easily accessible. . . . This work is above all things designed to be of actual value to the practitioner, to afford those engaged in mining, metallurgy, and industrial chemistry, a safe and authoritative guide which will keep them informed as to what is being done, and how it is done, in each department of the industry throughout the world.

T. C. H.

Honeycombed Limestones in Lake Huron. By ROBERT BELL.

In the Bulletin of the Geological Society of America, Dr. Robert Bell describes the honeycombed limestone of Lake Huron. It is found chiefly about Manitoulin Island, Indian Peninsula, and the area between these and Georgian Bay. The formation progresses faster in water fifty or sixty feet deep, but takes place in shallow water. It is found on the under side of overhanging rocks as well as on other surfaces. There are two principal forms of this erosion. In the first the cavities are elliptical, and neighboring ones tend to meet, giving a very spongy appearance. In the second the pits are finger like and crowded close together at the surface. They are usually shallow, but may be some inches in depth. The rocks in the vicinity of Manitoulin Island run from the Chazy to the Guelph. Dr. Bell finds the pits largest and most numerous in the dolomite of the Guelph formation. As to the immediate causes of the solution to which they are due, Dr. Bell cites an obscure concretionary structure in the rock, and an unusual amount of H_2SO_4 and sulphates in the water. He attributes the source of the sulphur compounds to the Huronian rocks that lie on the north of the lake. These are in part volcanics and rich in sulphides. He thinks solution is aided by hydrostatic pressure, free action of water and shifting currents.

Critical Periods in the History of the Earth. By JOSEPH L. LE CONTE.

The thesis laid down by the author is that "There must have been

some greatest revolutions which have in some way directly or indirectly affected the whole earth, and which may therefore be used to form the basis of the primary divisions of time." These he calls "Critical Periods" in the earth's history. The marks of such periods are readjustments of the crust of the earth, causing widespread changes in physical geography, affecting profoundly the climate of the whole earth, and causing marked changes in organic forms. These are indicated in the rocks by (1) widespread unconformities; (2) great, general, and rather sudden changes in organic forms; (3) the introduction of new and higher dominant classes; (4) the birth of great mountain ranges. Of these periods, beginning with the last, he enumerates the following—the Glacial revolution, the post-Cretaceous or Rocky Mountain revolution, the post-Palæozoic or Appalachian revolution and the pre-Cambrian revolution.

Of these it may be said—(1) they become shorter and shorter as we progress in the earth's history; (2) the effect of the introduction of new dominant types in producing changes in the whole organic kingdom steadily increases; (3) the oscillations of temperature have gradually increased. These periods hasten the steps of evolution and increase organic diversity, but diminish geographical diversity. These revolutions seem to be contrary to uniformity in the forces and laws of nature, but they are not so in reality. We may conceive of phenomena as being under the influence of two opposite forces, one progressive, the other conservative. Such will be more or less paroxysmal. Resistance at first prevails, and there is little change, but forces of change are accumulating, and finally resistance gives way and conspicuous changes take place rapidly.

Teepee Buttes. By G. K. GILBERT and F. P. GULLIVER.

In the Bulletin of the Geological Society of America, Gilbert and Gulliver have some interesting things to say of the Teepee Buttes of Colorado. They are found in a belt about ten miles wide and fifty to sixty miles long, at least, beginning at Little Butte Station on the Denver & Rio Grande Railroad, and extending to the south and east along that railroad. They are not continuous but gravel areas separate areas dotted with them. They are twenty to thirty-five feet in height, rudely circular, and diameter is usually less than height. The structure is peculiar, viz., a core of coarse, light-gray limestone, bedded and full of marine fossils, surrounded by a shale which has few fossils

and is rather easily eroded. There is no transition layer between the two, yet they interpenetrate somewhat. Processes of limestone surround portions of the shale, and lumps of limestone are found in the shale, moreover the limestone is roughly separated into beds by shale partings. They find that the steepness of the butte is a function of the rate of degradation of the surrounding surfaces, and that the height depends on the rate of degradation and the size of the cross section.

As to cause, the facts do not seem to be sufficient as yet. They favor the idea that the limestone cores are due to colonies of Lucina, more especially which dying on these sites left their shells to form the limestone while fine silts were forming the shales around. Why the molluscs congregated at these places and what caused the apparent mortality we are left to conjecture. They are interesting topographically and unique in some of their relations.

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